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AN ECOLOGICAL FRAMEWORK FOR ENVIRONMENTAL IMPACT ASSESSMENT IN CANADA

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SUMMARY

INTRODUCTION

Environmental impact assessment in Canada has evolved into a fairly complicated sociopolitical phenomenon involving extensive administrative support systems. However, there is a growing concern within the assessment community that the scientific requirements and implications of such highly developed administrative procedures have not received similar attention. This report presents the results of a two-year project designed to address this concern in the Canadian context.

The objective of the project was to determine the extent to which the science of ecology could contribute to the design and conduct of assessment studies and to recommend ways in which this could realistically be achieved. In so doing, it was recognized that ecological considerations represent only a portion of the total range of factors involved in environmental impact assessment. However, it was considered past the time at which the scientific substance of impact assessment should be examined in light of the requirements being dictated by procedural developments.

Beginning in June, 1980, the project was an undertaking of the Institute for Resource and Environmental Studies (IRES) at Dalhousie University through a contract with the Canada Department of Supply and Services. It was jointly funded by Dalhousie University, the Federal Environmental Assessment Review Office, Environment Canada, the East-coast and Arctic Petroleum Operators' Associations and the Canadian Electrical Association.

The Approach

By design, the project involved the active participation of environmental scientists who conduct impact assessment studies and those who are responsible for the administration of assessment procedures in Canada. Participants in 10 regional workshops, held across the country, included personnel from the federal and provincial governments, representatives of industrial proponents, consultants and members of the university community — some 150 people in total. The project also included a comprehensive review of literature pertinent to scientific and ecological inputs to environmental impact assessment. This report primarily reflects the opinions and suggestions emanating from the workshops coupled with the state-of-the-art in assessment studies as presented in the scientific writings.

Other project activities included: (i) extensive consultations with experts in the United States and Europe, (ii) a review of some 30 selected environmental impact assessments from across Canada and (iii) an in-depth evaluation of two impact assessments recently completed, involving detailed reviews of documents and interviews with key personnel.

An Advisory Committee was established to oversee and guide the conduct of the project. The committee, comprising senior representatives from government, university, industry, and the consulting community, met periodically to review interim results of the project and advise on forthcoming activities. The committee members, along with selected workshop participants, met in a final session at which the draft project report was critically reviewed. Dr. M. J. Dunbar of McGill University was retained as a senior external critic of the draft report.

The report is directed towards federal and provincial agencies administering assessment procedures, members of the consulting community directly involved in assessment studies, industrial proponents responsible for meeting impact assessment requirements, relevant professional organizations, those teaching courses on impact assessment at college or university levels, and various public interest groups which take an active interest in the assessment process. While the general text contains material of interest to the full range of target audiences, the recommendations have been directed toward specific groups which we perceive as having responsibility for implementation.

THE CANADIAN EXPERIENCE

An Historical Synopsis

The lack of attention to the scientific realities of environmental impact assessment has resulted in a gradual drifting apart of the two major groups involved. On the one hand are the administrators and their scientific advisors who are responsible for establishing the terms of reference for particular assessments and judging the adequacy of the resulting studies. In contrast are the project proponents and their environmental consultants who must translate the terms of reference into a study programme but are seldom sure of the scientific standards which the reviewers will finally adopt. The result has often been a somewhat confused and frustrating technical review process taking place within relatively well defined administrative procedures.

The result of this confusion over the appropriate scientific standards for impact assessment studies is a high level of dissatisfaction among those directly involved. Many of the workshop participants were not convinced that scientific quality is an important aspect of impact assessment studies. Others submitted that either we improve the scientific

jour of the studies which support the entire process, or e run the risk of seeing the concept of environmental npact assessment degenerate into an exercise in public lations and government lobbying.

Any substantial upgrading of the scientific quality of envi- nmental impact assessment is to some degree con- rained by the lack of common perspective among the articipating groups. From a scientific perspective, the asic dilemma is that environmental impact assessment is e result of public pressure and political motivation; its ori- ns cannot be traced back to either the requirements or utputs of science. Therefore, at one end of the spectrum e the government administrators who tend to see environ- ental assessment as the fulfillment of the required proce- ures or guidelines. At the other extreme are the research ientists who become involved in the development and view of impact assessment documents but often doubt hether it is an acceptable forum in which to rigorously ply the scientific method. From an industrial perspective, pact assessment is tied directly to project approval and ensing. Caught in the middle are the consultants who are pected to practice good science in a politically motivated stem.

As there has been little agreement on the objectives for pact assessment, there has been even less agreement on hat should be done at the applied level. As a result, no mmon operational definition of environmental impact sessment has emerged beyond the procedural direction ovided by government guidelines, policies or legislation. ither the practitioners nor the reviewers have had com- on reference standards with which to gauge the ecologi- requirements or merits of assessment studies.

The result of this combination of attitudes, perceptions d constraints has been very dilute application of scientific nciples and concepts to environmental impact assess- nt in Canada. The so-called 'shotgun' approach has pre- ed, with comprehensive but superficial coverage of all nents of the environment, regardless of their relevance project decisions. The review of more than 30 Canadian ironmental impact statements showed that, in general, y lacked a recognizable investigative design within which logical relationships could be studied. Rarely was there entral conceptual or analytical theme to guide the col- ion and interpretation of data. Predictions, where they urred, were commonly vague and of questionable value project decision-making. There is no evidence to indicate t the adoption of a more consistent ecological approach nvironmental impact assessment would pose extraordi- y operational difficulties. The few studies reviewed that involve a comprehensive ecological framework and e based on well-directed research programmes were npleted within the time normally available for impact essment studies.

me Major Problems

gnificant improvements in the scientific quality of ssment studies might be achieved if several major constraints can be reduced. Early in the project, five main constraints were identified as having an important bearing on the adoption of a more scientific approach to impact assessment:

(a) The need for a common standard — A clarification of what is an acceptable scientific basis for impact assessment studies would benefit everyone involved. The current state of confusion and differing expectations in this regard is counterproductive.

(b) The need for early agreement — Given the limitations imposed on impact assessment studies, it is important that those people conducting and reviewing assessments discuss as early as possible the basic approach to be adopted. The emphasis must be on maximizing the quality of work at the outset rather than unduly relying on a confrontational review at the end of the process.

(c) The need for continuity of study — All of the participants in environmental impact assessment must break out of the 'EIS syndrome'. The rationale for baseline studies and predictions of impact becomes rather tenuous without some follow-up monitoring to the project.

(d) The need for information transfer — Improving the scientific basis for environmental impact assessment would be greatly facilitated if everyone in the Canadian assessment community were aware of the most recent concepts, techniques and approaches as developed by imaginative practitioners and by the research community.

(e) The need for better communications — A forum for productive discussion and the exchange of ideas among those administering, conducting, reviewing and paying for impact assessment studies must be established. Resolution of the principal difficulties will be slow unless the major participants are aware of more than just the problems inherent in their own responsibilities.

A BASIS IN THE SCIENCE OF ECOLOGY

Science, Values and Decisions

Environmental impact assessment is grounded in the perceptions and values of society which find expression at the political level through administrative procedures of governments. Scientists are called upon to explain the relationship between comtemplated actions and these environmental perceptions and values. Although the views of the general public may not be supported by the findings of scientific investigations, their collective aspirations cannot be ignored. Therefore, it must be recognized that decisions resulting from environmental impact assessments may be based as much on subjective judgements involving values, feelings and beliefs, as on the results of scientific studies.

Based on the workshop discussions it is evident that in Canada this relationship between social values and the

scientific focus of assessment studies is generally recognized and accepted. The problems to be overcome seem less related to the importance of social values than their early identification and translation into appropriate environmental studies. There emerged from the workshops a number of ideas concerning the public perception of environmental values and their influence in the environmental impact assessment process. These included concern for: (i) human health and safety, (ii) potential losses of commercially or recreationally important resources, (iii) loss of endangered species and (iv) potential loss of habitat.

Social perceptions and values provide one means of determining the importance of potential environmental impacts. Another interpretation is that of statistical significance, involving the measurement of differences in the variations of ecosystem components affected by a project before and after it is initiated. It was acknowledged that this statistical interpretation of significance ignores the fundamental social focus of impact assessment and does not allow for any ranking of impacts by priority.

Some workshop participants suggested that the importance of environmental impacts should be based on ecological considerations. This was the most difficult interpretation of impact significance on which to develop a consensus. Eventually there was general agreement that impacts which resulted in the irretrievable loss of ecosystem components (e.g., gene pools) or functions (e.g., primary production) should be considered significant, although the ultimate concern could almost always be traced to human values.

It was amply demonstrated in the workshops and supported by the literature that environmental impacts of any magnitude can be deemed insignificant if they are not considered in project-related decisions. Fundamental to this concept is that one of the prime purposes of environmental impact assessment is to present relevant ecological information for consideration in project planning. We might consider this project perspective of impact significance to be most important in environmental assessment.

The following statement attempts to capture the essence of various perspectives on what constitutes a significant environmental impact:

> Within specified time and space boundaries, a significant impact is a predicted or measured change in an environmental attribute which should be considered in project decisions, depending on the reliability and accuracy of the prediction and the magnitude of the change.

The implications of the statement, for those who undertake and review assessment studies, are described in some detail in the report.

Peer Review

Good science can be defined as that which is acceptable to the scientific community as determined by peer review. It was argued at some workshops that the pressures of politics and time generally preclude the adoption of more rigorous scientific approaches to environmental impact assessment. On the other hand, there is a widespread conviction that studies which are found unacceptable through scientific peer review do not provide an adequate basis for assessing impacts.

The report questions the utility of peer review only *after* expensive and time-consuming studies have been completed and the project decisions are required. Obviously, it is in everyone's best interest to avoid having the credibility of the studies seriously questioned at that late stage in the assessment process. It is contended that external scientific evaluation must also occur in the conceptual and design phases of impact assessment studies, since the more conventional post-study peer review alone may be too late to influence assessment decisions.

The Recognition of Scientific Requirements

For some time, members of the scientific community have been stressing the need to clarify the scientific basis for assessment studies. The main scientific and technical requirements identified during the study are outlined below.

Boundaries — The establishment of time and space boundaries is a critical first step in impact assessment, although these are often assumed rather than stated. Like many other aspects of impact assessment, the setting of boundaries represents a trade-off, in this case involving: (i) the constraints imposed by political, social and economic realities (administrative boundaries), (ii) the spatial and temporal extent of the project (project boundaries), (iii) the time and space scales over which natural systems operate (ecological boundaries), and (iv) the limited state-of-the-art in predicting or measuring ecological changes (technical boundaries). It is important to distinguish between these categories since some are under the control of the investigators while others are relatively fixed.

Quantification — From a scientific point of view, if environmental impact assessment is to be substantially improved, the present preoccupation with descriptive studies must largely be replaced with a quantitative approach. Quantitative predictions cannot normally be made, nor hypotheses tested, without a firm foundation in measurement. The overriding constraint appears to be the high natural variability in many physical and biological phenomena. The problems posed by natural variation permeate nearly all scientific aspects of impact assessment and the limitations thereby imposed must be openly recognized. For example, within the time and resources available it may not be possible to establish true experimental controls under field conditions, nor to undertake the sampling programmes required to meet normally accepted confidence limits in statistical analyses.

Modelling — There was widespread agreement among workshop participants that conceptual and quantitative modelling are very useful and appropriate scientific tools for

npact assessment studies. Yet, they have received some-'hat sporadic use in the past. Conceptual modelling in par-cular was regarded as having an important early role in lanning an impact assessment since it can assist in provid-ıg some much-needed direction and focus for subsequent tudies. There has been considerable controversy over the pplication and utility of quantitative modelling, mainly with espect to its predictive capability. Quantitative modelling, specially computer simulation modelling, appears to be sed on a somewhat regular basis in certain aspects of nvironmental impact assessment such as those related to hysical transport mechanisms in the atmosphere or water odies. However, ecological effects modelling is generally onsidered to be unreliable for the purpose of predicting npacts.

Prediction — For most workshop participants, and as enerally reflected in the literature, environmental impact ssessment is equivalent to impact prediction — prediction changes from baseline conditions as demonstrated by e results of monitoring. In spite of this, prediction in npact assessment reports usually has amounted to gener-ized or vague statements about the possibility of certain onditions occurring. The lack of confidence in our predic-ons generally increases with expanding time scales and eater distances from the source of the impact. Added to ese difficulties is the overriding constraint posed by sto-iastic events which by definition cannot be predicted, though their influence can be incorporated into simulation odels. Assessment reports should clearly distinguish etween reasonably firm predictions, forecasts based on perience or professional judgement, and outright iesses.

Study Design — One of the most obvious shortcomings impact assessment is the lack of clear direction in the m of a study strategy or framework for investigations. ere are a number of tactical field and laboratory options ailable ranging from studies of controlled ecosystems icrocosms) to on site pilot-scale perturbations. Although e classic experimental design can seldom be adopted for pact assessment studies, much greater use should be ide of hypotheses and statistically-based designs. other recommended approach is to evaluate the environ-ental effects of similar developments previously com-eted (e.g., hydroelectric projects). Finally, in recognization our limited capabilities to predict ecological events, it y be necessary to consider the entire development oject in an experimental context and design baseline dies, predictions and monitoring programmes around need to verify hypotheses.

veloping an Ecological Perspective

t can be argued that the notion of impact assessment iates to applied ecology. In other words, the ranking of uired environmental studies by priority should reflect, in t, the extent to which the science of ecology has devel-ed a conceptual or theoretical knowledge base for the ticular phenomena of interest. The result should be a re limited and focussed study effort based on a compromise between the information needs of the decision-makers and what a sound, short-term, applied science programme can provide.

Lessons From Experience — The report presents a number of generalities to be considered in the adoption of a more scientific approach to the design and conduct of environmental impact assessments. These include:

(a) Always strive to develop a study design which assumes an opportunity to measure changes after project initiation.

(b) Strike a compromise between studying the valued ecosystem components and the nearest surrogate components for which useful predictions are possible; use professional judgement to extrapolate from the predictions to the valued ecosystem components.

(c) Take maximum advantage of the information which can be obtained from natural or man-made occurrences and natural records.

(d) Focus numerical data collection programmes around a statistical definition of natural variation in space and time.

(e) Refine a hunch concerning a potential impact until it can be stated as a specific question for which a numerical answer is possible, or stated as a hypothesis which can be tested.

(f) First attempt to predict project-induced changes in physical and chemical components and their direct impacts on organisms. Then focus attention on indirect effects operating through changes in habitat or food.

(g) It may be as important to consider the long-term potential of the ecosystem (or components of it) to recover from an expected impact, as it is to predict the initial outcome of the perturbation.

The Need to Conceptualize — The report gives high priority to the conceptualization of an environmental impact assessment within an ecological perspective of the project as well as the environment. An example of a basic conceptual framework for a project is given. In this case, individual construction or operation activities are considered to result in physical, chemical, biotic or energy components being introduced, withdrawn from or redistributed within a natural system as delineated by a set of boundaries. The role of the applied scientist is to determine whether these changes will result in changes in valued ecosystem components, either directly or through ecological relationships.

The logic sequence resulting from such an exercise can be quite simple or refined to a high degree of complexity. Regardless of the details involved, an attempt to place the project in an ecological framework should result in more focussed study effort having some or all of the following advantages:

(a) the separation of the project into manageable parts;

(b) a focus on the nature and source of the perturbation;

(c) the early establishment of time and space boundaries;

(d) a recognition of the valued ecosystem components as the focus for the assessment;

(e) a logical progession from physical-chemical to biotic attributes of the ecosystem;

(f) the consideration of functional ecological relationships wherever possible; and

(g) a recognizable format within which to present the study results.

Two basic but distinct approaches to conceptualizing the environment are suggested. One recognizes the hierarchical structure of ecological organization and the varying difficulties of measuring impacts at the individual, population, community and ecosystem levels. This forces the investigator to ask two fundamental questions: (i) at what biological level are the valued ecosystem components in question, and (ii) at what biological level is it possible either to usefully predict or to detect the expected perturbation? Unfortunately, in the majority of cases the concerns seem to lie at the population level, the very level at which our ability to predict or measure changes due to human activity is often weakest.

The second way of conceptualizing the environment for the purposes of environmental impact assessment involves a special look at the trophic structure. The linkages between the various levels become very important when dealing with impacts which are manifested in the species of concern through the food chain. The project, usually acting through alterations to the physical and chemical environment, may have its first effect on biota at any (or all) of the levels of the food web. However, such direct interactions are often not the case since the valued species are usually located high in the trophic structure while projects often interfere with species and ecological functions occurring at the base of the food web.

The ecological frameworks explained in the report are not presented as *the* models to be used for conceptualizing environmental impacts; rather the message is that the fundamental constraints and opportunities for assessment studies evident through even simple concepts should force investigators to contemplate the ecological realities of their proposed study programmes.

Ecological Scoping— Developing ecologically-based concepts of the project and the environment is a form of ecological scoping, as distinct from social scoping. While the latter depends on public opinion and perceptions, the translation of valued ecosystem components thus identified into appropriate ecologically-framed studies is the purview of the scientists. It might be said that social scoping is the establishment of the terms in which impacts should be *expressed* while ecological scoping represents the terms under which the impacts can be effectively *studied*.

The ecological scope of an assessment may be determined through answering the following basic questions:

(a) Is there reason to believe that the valued ecosystem components will be affected either directly or indirectly by the project?

(b) Is it realistic to attempt to study the effects on the valued ecosystem components directly?

(c) How can the effects on valued ecosystem components be studied indirectly?

(d) Is it necessary or helpful to use indicator components?

The report discusses in detail the implications of the answers to these questions in terms of designing and conducting assessment studies. Extensive use is made of examples from published material and the experience of the workshop participants to emphasize the practical direction that such an ecological scoping exercise can provide.

Developing a Study Strategy— Much of the report focusses on the fundamental requirement to think an impact assessment through first. More than any other single factor under the control of the investigator, it is this lack of an initial strategy for assessment studies that limits the effective deployment of time and resources. It may be said that environmental impact assessments, as generally conducted in Canada, have been long on tactics and short on strategy. Field surveys and inventories are tactical in nature and are seldom supported by a general strategy for the assessment studies.

The report discusses various elements which contribute to the development of a strategic basis for conducting environmental impact assessment studies. The following is a brief summary:

(a) We demonstrate how a generalized conceptualization of a project in its ecological and assessment context can help to clarify the relationship between, and focus attention on, the two most critical aspects of the assessment: (i) the physical, chemical, biotic and energetic nature of the perturbations, and (ii) the valued ecosystem components.

(b) We suggest that a consideration of the basic linkages between the project and the structural-functional relationships within an ecosystem would reveal the various possible interaction pathways between the initial perturbations and the valued ecosystems components.

(c) The objective in ecological scoping is to determine which interaction pathways offer the best opportunities for studies leading to a prediction or approximation of changes in the valued ecosystem components, given the constraints posed by time limitations, natural variability, the state of ecological knowledge and the scientific tools available.

Even the most cursory attention to the ideas embodied in these suggestions would force a reconsideration and refinement of the more conventional, unstructured and undirected approach to impact asesment, both in terms of the setting of objectives and the design of the studies to meet the objectives. Taken together, the above considerations,

in whatever terms they might be stated, set the stage for the establishment of an ecological strategy which would direct both the component, tactical studies, and provide a much needed basis for communication and understanding among all parties involved.

The report reviews in some detail the study strategies adopted for three different assessments — one based on natural succession, one based on bioaccumulation and one based on eutrophication. Although the examples provided are somehwat simplified, two generalizations are possible. First, the adoption of an overall study strategy will not constrain scientific innovation or the development of novel approaches. The scientists involved will be required to apply their full range of ecological knowledge and technical skills. Secondly, as many authors have previously emphasized, the major opportunities for developing predictive studies lie in the use of functional relationships or processes. Thus, a study strategy must incorporate some reasonably well understood ecological processes around which appropriate tactical studies can be designed.

Some consideration is given to problems of setting bounds on the physical and biological components of natural systems in an impact assessment, with some examples of how such boundaries have been established. It has been suggested that systems with relatively limited and well defined transport mechanisms in operation, such as lakes or watersheds, are easy to bound compared with oceanic and atmospheric systems. In any event, initial spatial boundaries for an impact assessment are often established on the basis of physical transport mechanisms, that is, primarily the forces of wind and moving water. Examples include oil slick trajectories and air emission plumes. In most cases a consideration of ecological relationships will expand the physical boundaries initially established, principally because of the high mobility of many species potentially affected by the project.

One of the most noticeable deficiencies in environmental impact assessment from the perspective of establishing appropriate ecological time boundaries is the lack of consideration of response and recovery times for ecosystem components potentially impacted. There is evidence to indicate that many ecosystems and population components are quite robust and have a high degree of resiliency. The report provides an example of a crude quantitative measure of the probability for the recolonization of indigenous species in an impacted aquatic system.

Organizing the Approach

The report attempts to provide some general direction with regard to the organization of activities inherent in developing an ecological approach to environmental impact assessment. They are discussed under three main headings as follows:

For Initial Understanding — Contrary to current practices, baseline studies should not be the first set of activities undertaken in an impact assessment. It is argued that such studies should be preceded by an ecological characterization. The objective should be to gain an appreciation for such features as the biological resources important to man, the major components of their habitat, the key biological processes and the main physical driving forces such as climatic conditions and transport mechanisms. Only after the results of the ecological characterization have been incorporated into the study strategy should baseline studies be undertaken. At this stage the potential range of basic ecological linkages between the project and the ecosystem will have been considered and the result of an ecological scoping exercise will have narrowed down the possible avenues for predictive studies and the need for specific information.

As might be expected, there are few examples where ecological characterization has been used in impact assessments in Canada. Precisely because of the lack of resolution provided by such an initial activity, we tend to have baseline studies in which the 'count everything' approach prevails. By contrast, the report adopts the more operative concept of baseline data as a statistical definition of the natural variability of phenomena of concern against which future changes can be predicted or measured.

A number of examples are given which show that the ideas embodied in the concept of ecological characterization are gradually being adopted and have proved helpful in focussing the study effort in impact assessment.

In Support of Prediction — Published material mentions the substantial advantages for prediction to be gained from studying the results of previous projects of a similar nature. And workshop participants referred to this too. It is somewhat surprising, then, to see the limited use made of this approach in impact assessment studies. While it is common for those involved in such studies to draw upon their general knowledge of previous projects or published sources, it is unusual to see an organized field programme directed towards that end. The report reviews the limited number of examples which were uncovered.

As was the case with the idea of studying previous projects, the workshop participants recognized the benefits to be derived from conducting pilot-scale perturbation experiments prior to the initiation of the project. It was also the case, however, that we could find little evidence from reviewing Canadian impact assessments where such experiments had been conducted. One particularly relevant example from Canadian impact assessment is described in detail to illustrate the practicality of the approach and the benefits to be derived from it.

For Testing Hypotheses — As a result of the project there has emerged a basic paradigm of impact assessment as viewed by applied scientists. Thus, baseline studies should be directed towards establishing quantitative descriptions of selected environmental attributes prior to the onset of the project under consideration. An effort then is made to predict the extent to which attributes will change as a result of the proposed project. The project may or may not proceed, in its original or altered form, depending on the predicted changes. In the event that the project pro-

ceeds, baseline variables are remeasured after project initiation to determine the extent to which the predicted changes have occurred.

The report demonstrates that there are practical tools available for developing a predictive capability but they must be included as integral elements of the assessment strategy adopted and the supporting tactical studies. Yet even the most optimistic applied scientist, using the best tools of the trade, will still recognize our very limited ability to predict ecological changes arising from proposed actions. As a result, there is a growing conviction that the project must indeed be considered in an experimental context in which post-project monitoring is required to test the hypotheses (the impact predictions). This is the only concept of impact assessment in which the interdependencies of the various activities — baseline studies, predictions and monitoring — become coherent in a scientific sense.

This may seem a somewhat theoretical concept of environmental impact assessment from an applied perspective. However, the underlying theme is very relevant, namely, that an impact assessment will not be completed until the results from monitoring are known.

There is some reason for optimism in this regard in the longer term. The report describes a few Canadian assessments that are currently underway or planned which committed to such an experimental approach. Although their overall design may not reflect the theoretical framework above, it seems clear that they are beginning to bridge the gap between the conventional impact assessment and applied ecological research.

REQUIREMENTS FOR ORGANIZING AND CONDUCTING ECOLOGICAL IMPACT STUDIES

The environmental assessment community in Canada has called for a set of basic requirements for ecological studies in support of impact assessment. Based on discussions at our workshops and on the literature, we have attempted to develop such a set of requirements which reflect expectations and standards well within the grasp and capabilities of those who organize and conduct assessment studies.

The requirements as stated below are structured so that they should be appropriate for impact assessments of all types of development projects in any geographic area, and they should be implementable under all environmental assessment administrative processes in Canada. They can be effectively applied at any level of sophistication or complexity desired.

The requirements should allow practitioners the maximum flexibility in practicing imaginative yet rigorous science in environmental assessment. They pertain to the planning and design stages of an impact assessment because scientific improvements are most effectively realized at these stages. They should be viewed as representing the minimum substantive content of the ecological studies in any impact assessment. However, individual assessments may have additional, more detailed scientific requirements imposed as deemed appropriate by the review agencies and practitioners.

The requirements do not deal directly with many of the principles, techniques and approaches discussed in the report. While such concepts have great application potential in environmental assessment (the text of the report advises on their use), the requirements were limited to such aspects as should be considered in great depth in every impact assessment.

Facilitating Implementation

How can a basic set of criteria for conducting environmental impact assessments be implemented? Since the requirements which follow will serve little purpose if they are not applied, the question of an appropriate implementation mechanism becomes crucial to the overall outcome of this research project.

It is not enough to say that the requirements should be adopted by the key groups participating in an impact assessment; this gives no indication of *how* they should be used. Nor is it sufficient simply to have the requirements incorporated into assessment guidelines since such requirements will need a scientific interpretation appropriate to each individual assessment. The best chance for implementation lies in having the requirements form the basis for joint planning of the impact assessment between proponents and the government agency administering the assessment review process.

All such agencies in Canada are urged to establish a core group of technical advisors for each impact assessment undertaken. The group would be expected to work with the proponent's scientific staff and consultants in developing a mutually agreeable design for the overall assessment *before* the individual studies are undertaken. This degree of co-operation will undoubtedly be criticized by those concerned with maintaining an 'arm's length' philosophy on the part of the agencies administering assessment procedures. However, by the same token, if we continue to consider co-operation as subversion, then there is little to do except develop longer and more complex guidelines.

The core group of advisors would be important participants in the final technical review of the assessment. In the event that the agreed assessment design was changed or not followed by the proponent, the core group would require justification. It would also be in a position to advise the review agency on the validity of the proponentès interpretation of the study results, a key factor in the process of impact assessment. The importance of the perceived independence and credibility of the government agency will have to be weighed against the pressing requirements to obtain the most reliable scientific data and advice possible. Obviously, some degree of compromise is necessary. In any event, it will always be the responsibility of the review

agency to interpret the final results of the assessment and makes its decisions on that interpretation.

One of the most important roles for a core advisory group would be to work with the proponent in developing an appropriate monitoring strategy and to assist the review agency in interpreting the results of, and limitations on, a monitoring programme.

In summary, the following "Requirements for Organizing and Conducting Ecological Impact Studies" could form the general framework within which the detailed plans for an impact assessment are worked out co-operatively by the core group of advisors to the agency and the scientific staff and consultants of the project proponent.

Requirement to Identify the Valued Ecosystem Components

ENVIRONMENTAL IMPACT ASSESSMENTS SHOULD BE REQUIRED TO IDENTIFY AT THE BEGINNING OF THE ASSESSMENT AN INITIAL SET OF VALUED ECOSYSTEM COMPONENTS TO PROVIDE A FOCUS FOR SUBSEQUENT ACTIVITIES.

(a) A variety of mechanisms may be appropriate for developing a set of valued ecosystem components. A social scoping exercise in which all interested parties are given an opportunity to submit opinions and suggestions is recommended. The means and criteria used in selecting the valued ecosystem components should be explicitly stated.

(b) The extent to which predicted changes in the valued ecosystem components are expected to influence project decisions should be made clear.

Requirement to Define a Context for Impact Significance

ENVIRONMENTAL IMPACT ASSESSMENTS SHOULD BE REQUIRED TO DEFINE A CONTEXT WITHIN WHICH THE SIGNIFICANCE OF CHANGES IN THE VALUED ECOSYSTEM COMPONENTS CAN BE DETERMINED.

(a) Criteria for impact significance should reflect statistical, ecological and social interpretations of the concept. Statistical interpretations should recognize difficulties in detecting project-induced changes in valued ecosystem components. Ecological criteria may include important natural processes such as primary production, and important ecosystem components such as major prey species. Social importance criteria may reflect a wide range of perspectives on the values attached to various ecosystem components.

(b) Terms used to describe the significance of project-induced changes in valued ecosystem components (e.g., major, short-term, regional) should be unambiguously defined. If they can not, reasons should be given. Such terms are subject to a wide range of interpretations in the absence of clear definitions.

Requirement to Establish Boundaries

ENVIRONMENTAL IMPACT ASSESSMENTS SHOULD BE REQUIRED TO SHOW CLEAR TEMPORAL AND SPATIAL CONTEXTS FOR THE STUDY AND ANALYSIS OF EXPECTED CHANGES IN VALUED ECOSYSTEM COMPONENTS.

(a) An assessment should acknowledge first the boundaries imposed for administrative reasons, and the consequent limitations on the utility of the assessment. Examples include multiple political jurisdictions and trans-boundary pollution problems.

(b) Within the administrative constraints, an assessment should identify the temporal and spatial limits as dictated by the project proposal. Examples include the duration of construction and operation phases of the project, and the spatial extent of physical structures and transportation corridors.

(c) Ecological boundaries are normally considered in relation to administrative constraints and project limits. In a spatial sense, ecological boundaries should reflect, among other things, transport mechanisms and migration. Temporally, they should reflect the response and recovery times of affected systems. Attention should be given to the level of resolution at which various ecosystem components are studied within the designated boundaries.

(d) There are technical constraints to meeting the desired objectives for the assessment apart from the administrative, project and ecological boundaries. Two examples of technical constraints include difficulties in undertaking adequate sampling programmes for some species, and difficulties in predicting changes in poorly understood ecosystem components.

Requirement to Develop and Implement a Study Strategy

ENVIRONMENTAL IMPACT ASSESSMENTS SHOULD BE REQUIRED TO DEVELOP AN EXPLICIT STRATEGY FOR INVESTIGATING THE INTERACTIONS BETWEEN A PROJECT AND EACH VALUED ECOSYSTEM COMPONENT, AND TO DEMONSTRATE HOW THE STRATEGY IS TO BE USED TO COORDINATE THE INDIVIDUAL STUDIES UNDERTAKEN.

(a) A study strategy should incorporate a conceptual outline of the proposed project in an ecological setting, as well as conceptual views of ecological structure and function within the receiving environment. This conceptualization would explore the linkages between the project and the valued ecosystem components through suspected cause and effect relationships.

(b) A process of ecological scoping should be used to determine the possibilities for investigating ecological changes. If an interaction between the project and a particular valued ecosystem component is

expected, the assessment should first explore how the interactions might be studied directly. If necessary, indirect avenues of study should be examined. Should the study and analysis of changes in certain valued ecosystem components be considered impossible, the assessment may resort to the study of relevant indicator components.

(c) Detailed studies are designed as a final stage in developing a study strategy. The assessment should make clear how every individual study undertaken contributes to the implementation of the study strategies developed.

Requirement to Specify the Nature of Predictions

ENVIRONMENTAL IMPACT ASSESSMENTS SHOULD BE REQUIRED TO STATE IMPACT PREDICTIONS EXPLICITLY AND ACCOMPANY THEM WITH THE BASIS UPON WHICH THEY WERE MADE.

(a) The predictive analysis should strive to ascertain the nature, magnitude, duration (timing), extent (geographic distribution), level of confidence and range of uncertainty of the predicted changes. Reasons should be given if any of the above cannot be ascertained.

Requirement to Undertake Monitoring

ENVIRONMENTAL IMPACT ASSESSMENTS SHOULD BE REQUIRED TO DEMONSTRATE AND DETAIL A COMMITMENT TO A WELL DEFINED PROGRAMME FOR MONITORING PROJECT EFFECTS.

(a) The design of a monitoring programme should be part of the development of a study strategy for any valued ecosystem component. Thus, baseline studies and predictions would be designed so that conclusive statements could be made once the monitoring studies are complete.

(b) An assessment should make absolutely clear the need for the results and the expected duration of the monitoring studies. The programme should remain flexible enough to be adjusted as appropriate to meet its objectives.

RECOMMENDATIONS

In addition to the Requirements for Organizing and Conducting Ecological Impact Studies, the research project has identified several other initiatives which would facilitate and encourage a more scientific approach to environmental impact assessment. The following recommendations pertain to the administrative and institutional aspects of impact assessment.

Recommendation 1 — Adoption of the Requirements

IT IS RECOMMENDED THAT ALL GROUPS ACTIVELY INVOLVED IN ENVIRONMENTAL IMPACT ASSESSMENT ADOPT THE REQUIREMENTS FOR ORGANIZING AND CONDUCTING ECOLOGICAL IMPACT STUDIES.

(a) Agencies that administer impact assessment procedures should incorporate the requirements into their policy documents and into assessment guidelines which they issue. As well, technical advisors should be requested to take the requirements into account when reviewing assessment studies.

(b) Project proponents should advise their environmental staff and consultants to adhere to the requirements when planning and undertaking assessment studies.

(c) Professional organizations and industrial associations should advocate the requirements as performance standards for their members involved in assessment studies, and should encourage their use as a basis for further study and elaboration by the professional community.

(d) Environmental consultants could use the requirements when preparing proposals to undertake assessment studies, and should adhere to them when designing and conducting such studies.

Recommendation 2 — Agency Advisory Committees

IT IS RECOMMENDED THAT AGENCIES ADMINISTERING ENVIRONMENTAL IMPACT ASSESSMENT PROCEDURES IN CANADA EACH ESTABLISH A SMALL COMMITTEE OF EXPERTS TO PROVIDE ADVICE ON SCIENTIFIC MATTERS RELATED TO ENVIRONMENTAL ASSESSMENT.

(a) The committee should review the policies and procedures under which the organization operates, and should advise on changes required to support a more scientific approach to assessment studies.

(b) The committee should assist the agency in ranking priorities for impact assessment research needs. Such ranking could include soliciting the opinions of proponents, consultants and research scientists, reviewing major research programmes relevant to environmental assessment, and informing research agencies of the main areas of knowledge deficiencies.

(c) The committee should encourage regular, non-adversarial meetings with representatives of the agency, proponents, consultants, research scientists and resource managers. Such meetings should address the current state of affairs in environmental assessment, should attempt to resolve outstanding issues, and should recommend changes in proce-

dures and requirements to continually refine the process.

(d) The committee should encourage the agency and other relevant organizations to co-operate in organizing and conducting impact assessment training activities, including technical workshops and short courses.

(e) The committee should advise the agency on initiatives to be taken in developing in depth studies on several major problem areas in impact assessment including socio-economic aspects, the cumulative effects of several projects in one area, regional environmental assessment, risk analysis, impact prediction and mitigation, and others. Such research efforts should involve broad based support and participation.

(f) The committee should advise the agency on initiatives to promote information transfer and dissemination. Initiatives of particular utility to scientific practice within impact assessment include a central storage and retrieval system for all environmental assessment reports and documents prepared under the agency's procedures, an up-to-date annotated bibliography of relevant research literature, and case studies of impact assessments which may serve as model approaches for certain scientific aspects of environmental assessment.

commendation 3 — Monitoring as Part of : Assessment Process

IS RECOMMENDED THAT ENVIRONMENTAL IPACT ASSESSMENT AGENCIES UNDERTAKE HATEVER PROCEDURAL CHANGES ARE NECES- ARY TO HAVE MONITORING FORMALLY RECOG- ZED AS AN INTEGRAL COMPONENT OF THE SSESSMENT PROCESS.

(a) Guidelines or terms of reference should place emphasis on monitoring of effects as an integral part of the design of impact studies.

(b) Environmental impact statements should provide as much rationale and technical detail for monitoring studies as for pre-project studies.

(c) Agencies should clearly establish for each environmental impact assessment the responsibilities of government agencies and proponents for conducting and reviewing monitoring programmes.

Recommendation 4 — Professional Involvement in Environmental Assessment

IT IS RECOMMENDED THAT ORGANIZATIONS AND INSTITUTIONS WHICH EMPLOY RESEARCH SCIENTISTS AND NATURAL RESOURCE EXPERTS ACTIVELY ENCOURAGE THEIR INVOLVEMENT IN ENVIRONMENTAL IMPACT ASSESSMENT.

(a) The organizations and institutions should stress the importance of co-operative research and study programmes as supportive activities for impact assessment.

(b) The contributions of research scientists and experts to environmental assessment should be recognized in performance appraisals and career advancements.

(c) Increased opportunities should be provided for employees to engage in short-term transfers of work or leaves of absence related to environmental impact assessment.

Part I

Introduction and Background

1 — INTRODUCTION

Environmental impact assessment in Canada, as elsewhere, has evolved into a fairly complicated socio-political phenomenon involving extensive administrative support systems. However, as pointed out by Munn (1975) at an international meeting of scientists, "The scientific community has the uncomfortable feeling that the institutional framework for environmental impact assessment is in place before the scientific basis has been established."

Although assessment practices have improved since then, there is still a widespread concern that a substantial gap exists between some of the basic concepts and their translation into scientific studies. This report presents the results of a two-year project designed to address this concern in a Canadian context. Thus, about eight years after the introduction and subsequent refinement of assessment policies and procedures throughout Canada, this is the first major effort to examine the technical requirements from the perspective of the applied scientist. Through the project, numerous people active in designing, directing, conducting and evaluating impact assessments were given the opportunity to review their collective experience and recommend ways of incorporating a more rigorous scientific approach into their future efforts.

The project, an undertaking of the Institute for Resource and Environmental Studies (IRES) at Dalhousie University, was jointly funded by Dalhousie University, the Federal Environmental Assessment Review Office (FEARO), Environment Canada, the Eastcoast and Arctic Petroleum Operators' Associations and the Canadian Electrical Association. By design, the project involved the active participation of environmental scientists who conduct impact assessment studies and those who are responsible for the administration of assessment procedures. Participants in 10 regional workshops, the core of the project, included personnel from the federal and provincial governments, representatives of industrial proponents, consultants and members of the university community. The recommendations contained in the report are directed to those who are responsible for the administration, conduct and review of environmental impact assessments in Canada.

The objective of the project was to determine the extent to which the science of ecology could contribute to the design and conduct of assessment studies and to recommend ways in which this could be realistically achieved. In so doing, it was recognized that ecological considerations represent only a portion of the total range of factors involved in environmental impact assessment. However, it was considered past the time at which the scientific substance of impact assessment should be examined in light of procedural developments. In effect, this report is an attempt to provide a common basis for reconciling somewhat unrealistic expectations within scientific limitations. If these concerns are addressed in a positive manner, the credibility and utility of environmental impact assessment will be greatly improved.

In some respects, the results of this project are not unique. As will become evident later in the report, many of the more general scientific and ecological problems associated with environmental impact assessment had already been identified in the scientific literature. Unfortunately, practical solutions were seldom suggested and when they were, apparently nobody paid attention. In that respect, this project is different. It has given high priority to the participation of a wide range of professionals, in various positions, who can translate the results of the project into a concerted effort to improve the scientific quality of environmental impact assessment. Given the wide range of involvement in impact assessment, an approach on such a broad front seems to have the best chance of resulting in substantial implementation of the recommended changes.

The report reflects the range of positive and negative perspectives on environmental impact assessment which prevail across Canada. On the negative side, there is a general feeling of frustration and lack of direction on the part of many of those conducting assessment studies. In some cases, there is confusion over what the studies are expected to achieve and what standards they are expected to meet. Also, although there are a large number of research publications dealing with ecology in environmental impact assessment, many of these suggest what should be done but provide few examples where the suggestions have been implemented. At a more basic level, there is evidence that many research scientists in Canada are reluctant to become directly involved in impact assessment since they feel that it is not an acceptable forum in which to apply the scientific method.

On the positive side, the project has demonstrated the interest and willingness of most people directly involved in impact assessment activities to upgrade the quality of their work through the adoption of some commonly accepted performance standards. The degree of commitment and level of support demonstrated by the agencies supporting the project is another important positive aspect. Furthermore, there are enough examples from across Canada to demonstrate the capability of the community of applied scientists to undertake more rigorous scientific studies as part of environmental impact assessment. The challenge is to modify existing administrative procedures and develop the necessary motivation to ensure a much broader application of this potential. In this regard, the recommendations in the report are directed both to the practicing scientist as well as to those administering assessment procedures.

This report is not a handbook for those conducting pact assessment studies, although they may find it help- in considering the appropriate scientific and ecological ımeworks within which to proceed. Nor is this report a sic textbook on ecology for administrators. It represents attempt to establish a common middle ground between ɜ current approach to impact assessment and the ideals en described in research publications. Through exam- ꞉s, those conducting assessment studies are encouraged take more advantage of the objectivity and organization ıerent in the scientific approach. At the same time, those ministering assessment policies and those paying for the dies are expected to adopt procedures which will ɔourage the required improvement in scientific integrity.

Even if all of the recommendations in this report were ɔpted and implemented, there would still be major prob- ıs associated with environmental impact assessment. example, this project did not address the topics of risk ılysis and cumulative effects, both of which are germane he concept of impact assessment. Nor was it within the ·pe of this project to examine the state of impact assess- nt research in Canada, an important supportive activity ch, according to Wallace (1981), is beset with problems. ally, our mandate did not include the socio-economic ɜ of environmental impact assessment, a topic which bably poses even greater challenges to the profession- involved, and almost certainly the aspect with the high- profile from the perspectives of the general public and decision-makers.

ı spite of the somewhat narrow focus of the project, we convinced that the adoption of the recommendations ɜin would be an important step in improving the sub- ıce and image of environmental impact assessment in ada.

꞉GANIZATION OF THE REPORT

ome words of explanation are in order concerning the ꞉entation of project results in this report. First, Part II esents the essence of the project findings on improving contribution that ecological science can make to envi- nental impact assessment. This involves two distinct intimately related aspects. On the one hand are the principles and methods of acceptable scientific practice, which essentially are shared by most other natural science disciplines (e.g., biology, oceanography, etc.). The other involves ecological principles and theory (e.g., succession, bioaccumulation, etc.), which are peculiar to the body of knowledge developed through the short history of the discipline of ecology. Chapter 8 attempts to elucidate the former in the context of ecological study as part of environmental assessment. Chapters 9 through 11 then consider ecological principles and theory as they may contribute to the design of assessment studies and to impact prediction.

In developing the recommendations, as much importance was given to assigning responsibilities for implementation as was given to developing the recommendations. Environmental impact assessment is a broad topic involving many participants and it is an excellent target for 'motherhood' suggestions. On the assumption that 'no responsibility' leads to 'no implementation', generalized recommendations have been avoided. If the assigned responsibilities are in error, perhaps the attempts to rectify the mistakes will lead to pointed discussions which otherwise might not take place.

To give full credit to the contributions of the workshop participants, they speak for themselves through numerous quotes inserted at appropriate locations throughout the text. The reader will often note conflicts of opinion between participants as well as disagreements with the main text. However, this is highly indicative of the current nature of environmental impact assessment. The quotes should provide the reader with a feeling for the range of opinions, ideas and suggestions to which the authors were exposed during the two years of the project.

Finally, throughout the report, emphasis is given to the use of examples to demonstrate the utility and practicality of the various concepts and approaches discussed. Environmental impact assessment writings are filled with rhetorical discussions on the advantages of various methodologies and techniques. Seldom, however, are they supported with concrete examples from actual impact assessments. We have attempted to draw upon as many Canadian examples as possible, both to show that the ideas presented have application potential and to illustrate the capability of those conducting assessment studies in this country.

2 — BACKGROUND TO THE PROJECT

The motivation for this project grew from a realization that the administrative and technical aspects of environmental impact assessment in Canada were getting seriously out of balance. By the mid 1970's, most governments in Canada had adopted the concept of examining the social and environmental consequences of proposed activities as part of the project planning process. For some, the requirements for impact assessment have become embodied in legislation while others administer assessment policies (see Couch (1982) for a summary of environmental impact assessment procedures in Canada). In all cases, however, administrative procedures have been developed and refined with little attention to the basic scientific problems inherent in the concept of impact assessment.

This lack of attention to the scientific aspects of impact assessment has resulted in a gradual drifting apart of the two major groups involved. On the one hand are the administrators and their scientific advisors who are responsible for establishing the terms of reference for particular assessments and judging the adequacy of the resulting studies. In contrast are the project proponents and their environmental consultants who must translate the terms of reference into a study programme but are seldom sure of the scientific standards which the reviewers will eventually adopt. The result has often been a somewhat confused and frustrating technical review process taking place within relatively well defined administrative procedures.

Through discussions with various individuals and agency representatives across the country, it became obvious that the confusion resulting from this imbalance was common within most impact assessment administrations. It also became evident that proponents and consultants were interested in attempting to rectify the problem since the current situation was considered wasteful of their time and resources.

Following consultations with a few key people in government, industry and consulting firms, a proposal was developed to review the general scientific and, more particularly, the ecological basis for impact assessment and to provide recommendations for improvement that would be relevant to the various agencies and organizations involved. The approach adopted was to ensure (i) the involvement of those people most directly associated with administering, conducting and reviewing impact assessment studies and (ii) equal participation by representatives from federal and provincial governments, industrial proponents, environmental consulting firms and universities.

The proposal was accepted by FEARO and formed the basis for a two-year contract, which began in July, 1980, between Dalhousie University (IRES) and the federal Department of Supply and Services. Funding was provided by the university, the federal government and industry.

OBJECTIVES

Basic Objective

The basic objective of the project was to develop comprehensive recommendations whereby the principles of ecological theory can be applied to environmental impact studies and related activities.

The sub-objectives were:

(a) to determine the extent to which ecological principles and techniques have been applied to environmental impact assessments in Canada and document areas where such applications would have significantly improved the quality of impact statements;

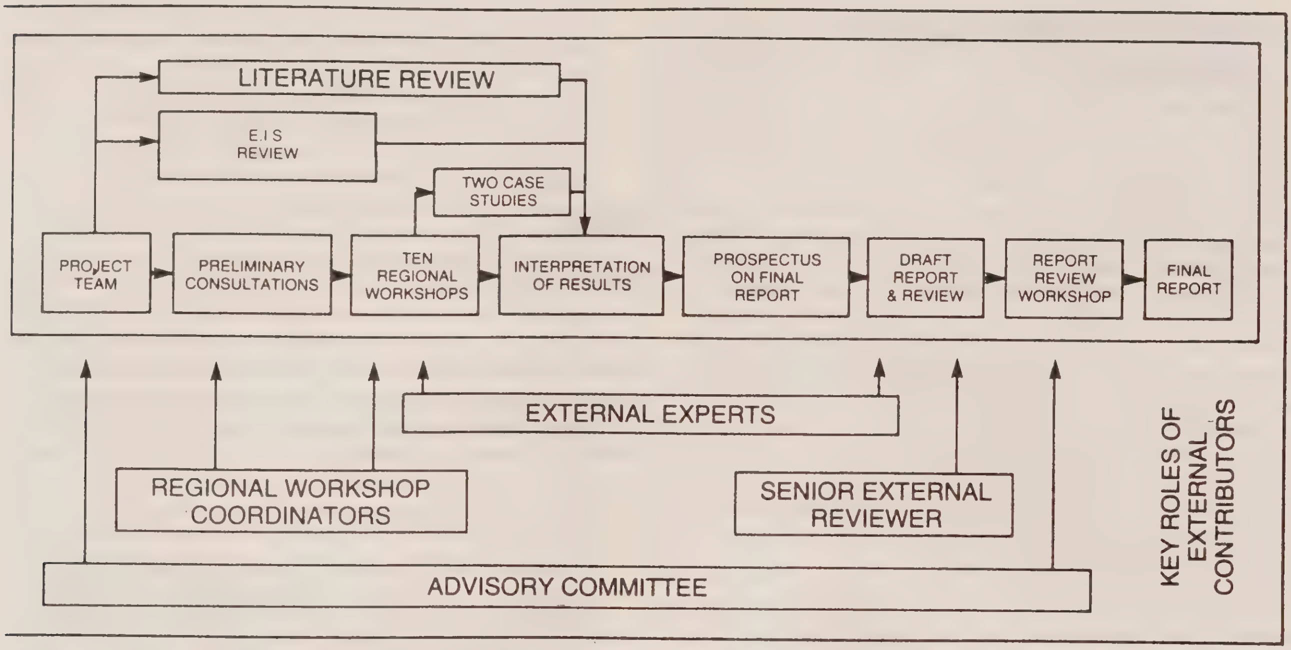
(b) to provide guidance on the application of ecological principles and techniques in the formulation of impact assessment objectives, adoption of study designs, the collection and analysis of data and the interpretation of such data for the purposes of assessing and evaluating environmental impacts;

(c) to make specific recommendations regarding the application of the above guidelines in related programmes and activities including environmental baseline studies and post-project monitoring requirements; and

(d) to evaluate the potential for incorporating such guidelines within a legal framework related to impact assessment procedures.

Two important points deserve attention relative to the project objectives. First, the project was expected to concentrate on ecological concepts and principles as applicable to environmental impact assessment. However, since ecology is a science, it incorporates scientific methods and principles common to other disciplines. For example, it quickly became apparent that discussions on the application of accepted statistical procedures for the collection and analysis of data were germane to the topic. As a result, the focus for the project was somewhat broadened to ensure that the full range of scientific concerns was addressed.

The second point is that the Advisory Committee, after examining the potential for adequately addressing the legal aspects of the project topic, recommmended that subobjective (d) be deleted. Consequently, no effort was made to address the legal issues.



GURE 2-1 PROJECT ACTIVITIES NETWORK

TUDY ORGANIZATION

dvisory Committee

At the time project started, a national Advisory Commit- was established to oversee and guide the conduct of project. The membership of the committee reflected a oad range of professional disciplines and affiliations, the ter including government, university, industry and the nsulting community. As well as meeting periodically oughout the project to review interim results and advise forthcoming activities, the Advisory Committee provided ier input including reviewing the draft final report.

eview of Environmental Impact Statements

The project included a critical evaluation of the extent to ich ecological principles have been applied to environ- ntal impact assessments conducted in Canada. The iew involved 21 assessment reports and provided a sis upon which to plan for discussions at the technical rkshops.

erature Review

n ongoing review of writings pertinent to scientific and logical inputs to environmental impact assessments was ated at the beginning of the project. From various rces including scientific journals, limited-distribution nposium proceedings, government and consultant reports, theses, and standard textbooks, a collection of a few hundred items was established. Publications addressing the specific objectives of the project are relatively scarce, and it was necessary to search printed material that is rather peripheral to the project focus. An annotated bibliography will be published as a separate volume.

Regional Workshops

The project was structured around ten technical workshops held across Canada within a one-year period . Each workshop was attended by impact assessment practitioners, reviewers and scientists from industry, governments, universities and the consulting community. Participation was limited to professionals in the physical and biological sciences who were reasonably close to field responsibilities and who had experience in, or a good working knowledge of, environmental impact assessment as it is practised in Canada. Appendix A provides names and affiliations of the participants at each workshop and Appendix B shows the distribution of affiliations.

In order to stimulate the broadest range of thinking amongst participants, few constraints were imposed on the discussions at the workshops. First, although the terms of reference focussed specifically on the ecological basis for environmental impact assessment, this was somewhat broadly interpreted by most participants to include scientific investigation in general. It was understood, however, that the socioeconomic implications of resource developments were not the focus of discussion, although a number of participants were motivated in this direction.

Secondly, environmental impact assessment was defined for discussion purposes as a process, or sequence of activities, beginning with a pre-project data acquisition programme (the baseline study), followed by an interpretive, predictive and evaluative phase (the preparation and review of an impact assessment report) after which post-construction environmental assessment continues for some period of time (the monitoring programme). This definition, far from being a constraint, encouraged the participants to consider the overall approach rather than restricting their thinking to the familiar Environmental Impact Statement (EIS) which is all too often the main focus for bureaucratic and public attention.

To provide a mechanism whereby discussions at the workshop could advance from a general level to the specific, hypothetical development scenarios were described in the background material circulated to all participants. While a number of approaches were used in considering the scenarios, in each case the participants had an opportunity to test some of the ideas generated during the workshops and to evaluate their applicability. Although not equally successful in all workshops, the consideration of scenarios proved to be a necessary adjunct to the more conceptual and unstructured workshop discussions.

Finally, the participants were given the opportunity to answer a series of questions, either individually or through group discussions. While the questions evolved over the time period from the first workshop to the last , they provided a common denominator for all workshops. The questions were general in nature so as to have equal relevance to the wide range of disciplines involved. Therefore, they were also subject to wide interpretation. Some consensuses were expected to emerge as a result of analysing the individual responses and the relevant portions of the group discussions.

Case Studies

Appendix C deals with an in depth look at two recent Canadian environmental impact assessments. These case studies were undertaken to determine the operational constraints against or opportunities for, the application of the main ecological assessment concepts identified during the workshops. The studies involved a review of the documentation for each assessment and a series of interviews with consultants and representatives of government agencies and proponents who had special roles in undertaking or reviewing each assessment. The results have helped in gaining an understanding of what can realistically be achieved in assessment studies from a scientific perspective.

Interpretation of Results

The five major sources of information leading to the production of this report included the review of printed material the EIS review, the preliminary consultations, the regional workshops, and the case studies (Figure 2-1). While the EIS review and the case studies are discussed separately (Chapter 4 and Appendix C respectively), the results from the literature review and the workshops are combined and provide the basis for the document. Discussions at each of the regional workshops were recorded on audio tape. Following the workshops, the tapes were analyzed and the results summarized. This report only makes distinctions between workshops to provide specific examples where appropriate.

The Prospectus

A prospectus on the final report was widely circulated, amongst workshop participants and others, with the intention of providing an early opportunity for comment on the premises and assumptions which would be reflected in the approach to drafting this report. While unanimity on these basic matters among such a large number of people was not expected, it was hoped that some level of agreement at that stage would reduce the need for major changes at a later draft stage when fundamental disagreements or misunderstandings would be much more difficult to resolve. Comments on the prospectus were instrumental in pointing out topics requiring further elaboration, more emphasis, or re-direction.

Review Procedures

The draft final report was widely circulated for review among workshop participants and other interested parties. In addition a final review meeting was held involving selected workshop participants and the Advisory Committee. Also, Dr. M. J. Dunbar of the Marine Sciences Centre at McGill University in Montreal was retained to provide extensive critical review of the draft final report.

TARGET AUDIENCES

Based on discussions with workshop participants and other interested parties, the project results could influence a number of agencies and organizations with respect to their involvement in, or responsibility for, environmental assessment activities in Canada. The following examples indicate the range of potential users and interests:

(a) Professional organizations, such as the Canadian Society of Environmental Biologists, may find the results useful in formulating standards of good practice as a reference for the future involvement of their members in environmental impact assessments.

(b) The results are expected to be of use to consultants and project proponents in preparing and evaluating proposals to undertake impact assessments. Even the preliminary ideas presented in the Progress Report (Beanlands and Duinker, 1981) have been reported to be helpful in this regard.

(c) There is increasing evidence that provincial and federal government agencies and industrial proponents

hope to use the project results in evaluating their impact assessment procedures. It is evident, for example, that substantial changes are required in assessment guidelines if major difficulties are to be resolved.

ɟ) The content of this report is expected to provide some direction for governments and industrial proponents in planning long-term co-operative programmes of environmental research and monitoring.

ɘ) The results of the project may be incorporated into environmental impact assessment courses given at various universities and community colleges across the country. Requests have already been received for specific material and information, and the demand is expected to increase.

) The report should be of value to various public interest groups which take an active role in the environmental assessment process.

ɪviously, not all of these potential user groups will have l interest in all aspects of the project. However, the t has been designed and written to be of use to a ɟ audience through a balance between technical s and implications for environmental assessment in a ɟer perspective. While the general text contains ial of interest to the full range of target audiences, we directed specific recommendations to those groups we believe should bear the major responsibility for menting them.

INITIONS OF TERMS

ierous common and technical terms are used within ɔort in very specific contexts. In this section we define l of these terms in order to clarify their use in this

onmental Impact Assessment (EIA)

term is used synonymously with *environmental ment* and *impact assessment*, and it refers to a pro- set of activities designed to contribute pertinent mental information to project or programme deciıking. In doing so it attempts to predict or measure ironmental effects of specific human activities or do ıd to investigate and propose means of ameliorating fects.

ɔnment

ɘrm *environment*, in the context of the environmenct assessment, has come to include the social and ic milieu of development proposals as well as the (biophysical) environment. This report recognizes ɔrtance of all three elements, but deals only with of environmental assessment that pertain to the nvironment.

Ecological Principles and Concepts

Ecological principles and *ecological concepts* refer to basic truths, theories, or working hypotheses about the relationships of organisms or groups of organisms with their environment. In the report, principle is used in the positive sense, concerned with scientific concepts, rather than in the normative sense which is concerned with moral or ethical value judgements (Norton and Walker, 1982). Such positive principles or ecological concepts may range from general statements that are basic to the science of ecology, to detailed principles as developed within specialized scientific disciplines. We refer the reader to a recent paper by Walker and Norton (1982) for a preliminary set of some 30 positive ecological principles that are of use in designing and conducting environmental impact studies.

Ecological Approach vs Ecosystem Approach

An *ecological approach* to environmental impact assessment is one that makes optimal use of ecological principles and concepts in the design and conduct of assessment studies and in the prediction of impacts. An *ecosystem approach* to impact assessment is one in which impact studies and predictions concentrate on phenomena and variables at the community and ecosystems levels. In advocating the former, this report simultaneously endorses a systems approach to environmental assessment, and recognizes the critical importance of ecosystem theory and principles in adopting an ecological approach. We caution against the exclusive use of an ecosystem approach as defined above on the grounds that environmental impact assessment will likely achieve its greatest influence on project or programme decisions through information about species populations for which there is public or professional concern or both.

Social Scoping vs Ecological Scoping

Social scoping refers to a very early activity in an impact assessment in which an attempt is made to identify the attributes or components of the environment for which there is public or professional concern, or both, and to which the assessment should primarily be addressed. On the other hand, *ecological scoping* is defined as an exploration of the possibilities for studying and predicting the effects of a planned action on the attributes or components so defined. Thus, social scoping establishes the terms in which impacts should be expressed, and ecological scoping establishes the terms under which the impacts can be studied and predicted.

Valued Ecosystem Components

Each of the environmental attributes or components identified as a result of a social scoping exercise is referred to as a *valued ecosystem component*. These may be deter-

mined on the basis of perceived public concerns related to social, cultural, economic or aesthetic values. They may also reflect the scientific concerns of the professional community as expressed through the social scoping procedures (i.e., public hearings, questionnaires, interviews, workshops, media reports, etc.).

Study Tactics and Study Strategies

We have borrowed two terms from military usage, as suggested by Bella and Overton (1972), for describing levels of study organization in environmental assessment. A *study strategy* is considered an overall plan used to co-ordinate various individual activities and sources of knowledge in seeking answers (e.g., predictions or hypothesis tests) concerning specific effects on valued ecosystem components. A *study tactic* represents a component study within the strategy which contributes specific, partial knowledge toward the answer sought. Examples include distribution and abundance surveys, laboratory experiments and simulation modelling exercises.

Ecological Characterization

"An *ecological charaterization* is a description of the important components and processes comprising an ecosystem and an understanding of their functional relationships", (Hirsch, 1980; emphasis added). Such a characterization should include information on the biotic resources important to man (including important features of their habitat) and key biotic processes (e.g., climate, and transport mechanisms). An ecological characterization is an early step in an environmental assessment, and it depends primarily on information from reconnaissance surveys and the published material, co-ordinated by a conceptual modelling exercise.

Baseline

We use the term *baseline* to mean a description of conditions existing before development against which subsequent changes can be detected through monitoring, (after Hirsch, 1980). To fulfill this role, baselines normally must consist of statistically adequate descriptions of the variability inherent in the valued ecosystem components prior to the onset of the planned action. As such, the baseline study itself is not a predictive tool, although it does describe the condition from which a valued ecosystem component is predicted to change.

Prediction

Combining definitions from a few common dictionaries, we define *prediction* as an assertion based on calculation, knowledge, or shrewd inference from facts or experience, in advance of proof. The term *forecast* can be used synonymously, although it often implies on assertion based on transparent conjecture, that is, its basis in opinion is publically disclosed. We have not differentiated between a prediction and a forecast in this report. In the context of environmental impact assessment, we submit that a prediction or forecast is incomplete without an explanation of the basis upon which it was made.

Monitoring

Monitoring simply means repetitive measurement. In the general context of environmental impact assessment, it usually refers to the measurement of environmental variables after a development proposal has been initiated (the baseline constituting such measurement before project initiation). In the specific context of ecological investigations within impact assessment (i.e., the context of this report), our use of the term monitoring refers to repetitive measurement of specific ecological phenomena to document change primarily for the purposes of (i) testing impact hypotheses and predictions and (ii) testing mitigative measures.

Conceptual Modelling and Quantitative Modelling

We use the term *conceptual modelling* to refer to an organized exercise of: (i) identifying the relevant system components, (ii) qualitatively identifying the system structure, and (iii) developing a flow diagram of the system. The main purpose for the conceptual model is to explicitly organize the preliminary understanding of ecological structure and function (i.e., components and processes).

On the other hand, *quantitative modelling* is used to refer to the construction and use of mathematical representations of ecological phenomena and relationships. As such, it may involve statistical analyses, simulation modelling, and several other forms of mathematical manipulation of data.

We emphasize that conceptual modelling and quantitative modelling are not mutually exclusive; in fact, they are often fused into a modelling exercise that progresses from the former into the latter (e.g., Holling, 1978). However, conceptual modelling usually connotes an earlier, qualitative effort at systems understanding, whereas quantitative modelling connotes a later, more detailed numerical exercise.

Indicator of Change

The term *indicator* is used to denote either (i) a biophysical component or variable which is monitored to detect change in that component or variable or (ii) a calculated index of the condition of all or part of an ecosystem. Such indicators are considered to be generally unrelated to the valued ecosystem components identified for the assessment. Biophysical components or variables that are related to, and used to indicate the condition of, the valued ecosystem components have been termed *surrogates*.

As an example, suppose an adult fish population has en identified as a *valued ecosystem component* in an sessment. *Surrogate* components for this population may lude the species' larval population, the species' habitat, or a major prey species. An *indicator of change*, should the adult population itself or its surrogates not be amenable to investigation, may be species diversity within aquatic communities, or specific conductance of water.

3 — DEVELOPMENT OF THE PROBLEMS

AN HISTORICAL SYNOPSIS

Those who have been responsible for preparing the voluminous environmental impact statements currently in vogue can probably blame their counterparts who undertook the assessment for the Trans-Alaska Pipeline in the early 1970's. In that case, a federal judge ruled that an initial 8-page EIS for the 1 900 km. construction road was unacceptable. According to Norton (1979):

> "Ever since that court's finding, and the granting of an injunction delaying a federal permit for a road, Environmental Impact Statements have been long, heavy, multiple-volume documents. The Final Environmental Impact Statement for the trans-Alaskan pipeline, for example, comprised six fat volumes of environmental text, plus three volumes of economic and security risk analyses, plus eventually four volumes of public testimony on the nine preceding volumes."

Impact assessment administrations were established in Canada with the expectation of receiving such voluminous documentation. At least that could have been anticipated from guidelines which normally included the full range of possible environmental concerns. Initially, most guidelines for assessments in Canada emphasized biophysical phenomena. However, in recent years social and economic considerations have been accorded equal importance. This is a reflection of the gradual evolution which has occurred in the concept of environmental impact assessment. It was initially considered to be another administrative mechanism for environmental protection. It gradually grew into more of an environmental and socio-economic planning exercise with the proposed project providing a geographical focus. More recently, some impact assessments are emerging as comprehensive regional planning exercises such as for the Beaufort Sea Hydrocarbon Development Project and the James Bay Hydroelectric Development. In effect, an ever-broadening range of interests, concerns and objectives are being 'piggybacked' onto environmental impact assessment.

One of the results has been the preparation of longer guidelines leading to more voluminous documentation. As was noted numerous times during the workshops, draft assessment guidelines inevitably grow in length as they are circulated among various government agencies for comment and are reviewed by the public. The result is that environmental impact statements are now written with the objective of meeting so many diverse requirements that extensive coverage of all issues takes precedence over a more focussed but rigorous examination of those which appear most critical. It is little wonder that basic scientific and ecological aspects of assessment studies have not been given a high priority.

Yet the technical reviews to which assessment documents are often subjected are becoming more demanding. It is now common for experts from government resource departments or research agencies to review environmental impact statements and comment on them in public hearings. At the same time, environmental groups have become more sophisticated in their review procedures, often hiring consultants to analyze documents and to prepare technical arguments.

The result of this conflict between the demand for quantity versus quality in impact assessment studies has been a high level of frustration and dissatisfaction among those directly involved. Many of the workshop participants were not convinced that scientific quality is an important aspect of impact assessment studies. Others believed that without greater attention to the integrity of the studies undertaken, the resulting recommendations arising from assessments would be subjected to increasing public ridicule. Environmental impact assessment, after a decade of existence, is considered to be at a crossroads — in the longer-term it must move along the path toward comprehensive environmental planning. However, such basic changes in the philosophy of impact assessment will be slow to shift recognizably from the conventional project focus at present. Planning ideally involves many elements of society working together to establish and support common goals. Some of these elements, such as government and industry bureaucracies, have tremendous inertia, and it would be unreasonable to expect a new common philosophy or ethic of environmental planning to emerge overnight.

But there is a more immediate crossroads — either we improve the scientific rigour of the studies which support the entire process, or we run the risk of seeing the concept of environmental impact assessment degenerate into an exercise in public relations and government lobbying.

DIVERSE PERSPECTIVES

"A hopeless generalist may be able to do a better EIA than a heavy-duty specialist."

"The purpose of EIA is to get approvals."

"The purpose of EIA is also to prevent approvals!"

"EIA equals minimum regret planning."

Any substantial upgrading of the scientific quality of environmental impact assessment is to some degree constrained by the lack of a common perspective among the major participating groups. The following is a brief summary of the conflicts of interests and objectives which permeate nearly all aspects of impact assessment as practiced in Canada.

ɘ Administrators Perspective

overnment administrators tend to view environmental act assessment as the fulfillment of required procedures ;et by policy or legislation. For these people, it often omes a matter of whether the assessment guidelines ɘ been met. In most cases the first priority is on running administrative machinery of assessment with less ırd for the details of the resulting studies.

though the agencies may retain outside experts for the aration of guidelines, such terms of reference usually unt to lists of "things to do" rather than providing any of scientific direction or performance standards. It is at the review stage that the administrators are faced determining the scientific or technical substance of the ssment studies undertaken. At this time, outside ·rts may be brought in to give their opinion. In doing so, experts almost invariably adopt a fairly rigorous interation of the guidelines — a perspective which may have ɘd at the beginning of the assessment but which can ɘry disruptive at the end.

Ve feel the objectives of EIA should be to ensure that ɘ proponent has a global perspective, to ensure that ɘ appropriate information gets to the public, and to empt to improve decisions."

he attitude of government is that EIA is a matter of blic expenditure — its politics versus dollars."

IA is not a scientific activity, but a planning process.

owever, it does require a great deal of scientific out."

Proponents Perspective

ndustry, the objective of environmental impact assess- is tied directly to the project approvals and licences. use of the high public profile which is often adopted in v procedures, impact assessment is also important to try from a public relations perspective. With project oval in mind, the proponent's main objective is to op an acceptable EIS. They will 'do what has to be to get that document approved, but are understand- eluctant to consider anything beyond that as part of npact assessment process. This EIS focus may nt problems when it comes to implementing impact sment in much a broader time frame as implied by the ion of operation-phase monitoring.

ɘems that not all industrial proponents believe it is in oest interest to have the scientific quality of impact sment studies improved. A certain degree of flexibility dy results can sometimes be used to advantage when ng potential impacts. On the other hand, there is evidence to indicate that industrial proponents in la have generally adopted a positive attitude towards nmental impact assessment. As stated on a number casions during the workshops by various industrial entatives, 'Any reasonable study will be funded.'

"The cost of delaying a project because of impact assessment studies is prohibitively high given our current interest and inflation rates."

"To industry, EIA is a small pain in the butt."

"Industry complies with guidelines and government agencies just to keep everyone happy."

"Proponents tend to hide the facts on negative impacts."

The Consultants Perspective

In Canada, the task of conducting environmental impact assessment studies and preparing an EIS most often falls to consultants in the employ of the proponents. They find themselves caught between the differing perspectives on the assessment process held by government agencies and proponents. The consultants' main role is to translate assessment guidelines, which are often generalized and vaguely worded, into a number of field or laboratory studies or both. Basically, they try to establish a short-term applied research programme. In so doing, they are normally directed by their clients to limit their efforts to a level which is necessary to get the project approved. However, they must also consider the possibility of project delay or refusal if the studies are found unacceptable to the reviewers. In effect, the consultants are expected to practice good science in a politically motivated system.

In many respects, the role of the consultants in environmental impact assessment is the most difficult of all. They do not have the luxury of working according to their own fundamental objectives for the assessment process. They must develop a compromise between the approval required by the client and the scientific and technical standards which they would like to adopt to ensure acceptance within a process that is essentially a peer review.

"The core of the consultants' dilemma is to devise a defensible, credible method for undertaking impact assessments."

"Consultants like to practice good science, but there is usually not enough time."

The Research Scientists Perspective

Research scientists in government and universities have not generally been attracted to environmental impact assessment. From their perspective, the overriding constraints of time and politics usually preclude the conduct of acceptable science in assessment studies. They are, however, often called upon to assist in the preparation of assessment guidelines. Since the guidelines are seldom written in a contractual format which would guarantee the conduct of acceptable work, their basic suspicion of impact assessment tends to be confirmed.

As well, government and university researchers and staff of resource management agencies are often called upon to review the results of impact assessment studies. In so doing, they wear their scientific hats and evaluate the stud-

ies according to standards of excellence which are rarely established at the outset. In effect, they undertake a peer review of the work in much the same way as they would evaluate an article submitted for journal publication. This amounts to implementing a quality control programme at the end of an assembly line with no feedback loop. It is frustrating to both the reviewers and authors of the documents.

"EIS is often a rationalization of an already-made decision."

"EIA is often used as weaponry amongst camps of ideals."

"The reason good science is not practiced is because EIA is a political process."

An Example — Monitoring

We have described four major perspectives on various impact assessment activities as brought forth at the workshops: there are undoubtedly more. Environmental monitoring provides an excellent example of the divergence of these perspectives on one particular aspect of impact assessment:

(a) Industrial proponents have biased motives for environmental monitoring after project completion. They normally will only consider establishing a monitoring programme when required to do so under permit regulations, as a reference base for possible compensation claims, in order to generally facilitate project approval (i.e., public relations) or as a basis for arguing against over-regulation.

(b) From the perspective of government officials, the results of post-project monitoring can be used to assess the extent to which recommended mitigation measures are effective and to compare effluent levels with established standards.

(c) The scientist looks upon monitoring as a means of hypothesis testing or checking the validity of predictions which in the long-term will lead to a better understanding of cause and effect relationships between man-induced perturbations and environment.

ROOTS OF THE FRUSTRATIONS

"It is clear that there is little agreement on what studies should be done for EIA and on what goes into an EIS."

"The problem is that proponents lose interest in an EIA once the project has been approved."

"The guidelines we get now are so fuzzy, they fit anything and nothing!"

"Either no guidelines are given, and the direction comes from the consultant himself (who is usually biased), or too many guidelines are given, and EIS gets watered down because everything has to be looked at."

As mentioned previously, the rationale for this research project was the need to allow the grumbling impact assessment community in Canada to have a chance to vent frustrations and to recommend ways of achieving a greater degree of ecological integrity within the process. Several factors contributing to this unsettled state of affairs were evident early in the project, and these subsequently provided the basis for beginning the study.

Perhaps first and foremost was the lack of a common perception of the purpose of undertaking environmental impact assessment, as outlined in the previous section. As there has been little agreement on what impact assessment should do, consequently there has been even less agreement on what should be done at the applied level. Coupled with this notion is the lack of a common understanding and expectation of what can realistically be achieved from a scientific perspective. A wide range of perceptions has been evident, ranging from the conviction that impact assessment is not a place for science, to the belief that scientific study can provide any of the answers needed. As a result, no common definition of environmental assessment has existed beyond the procedural direction provided by government guidelines, policies, or legislation. Neither the practitioners nor the reviewers have had common reference standards with which to gauge the ecological requirements or merits of an impact assessment.

Until now, environmental assessment has largely been a pre-development activity. From the point of view of administrators, proponents and reviewers, this may be advantageous since the process has a well defined cut-off point beyond which time those involved can move on to other projects. Indeed, most of the processes established across Canada for administering impact assessments were not designed to deal with longer-term, ongoing activities. This characteristic has been a great source of frustration to those who plan and carry out assessment studies. Not only is the time inappropriately short within which to undertake such studies but little opportunity or stimulus has been given for the examination of actual impacts from development projects. Monitoring during the operational-phase of projects is considered to be critical to improving the knowledge base for impact prediction.

The perception that environmental impact assessment is a politically motivated process has also contributed to the frustration level of practitioners. For those who conduct the studies and present the results, it has often been difficult to sense any influence of the findings in decision-making. As well, there has been a ubiquitous negative sentiment towards the assessment guidelines under which most practitioners have had to operate. Such guidelines reportedly have not allowed scientists the freedom to apply their own experience and judgement in planning, designing and undertaking studies.

It became evident shortly after the first few workshops that a serious lag in information transfer exists between the research community which explores and develops new concepts for impact assessment, and the practitioners and reviewers regularly involved with assessment studies. The

eat deal of information that we have been able to uncover ′ systematically searching the relevant published sources ›parently had not been reaching the hands of most gov- ɿnment and industry personnel and consultants. We sug- ·st that this has been an important factor in prolonging ɘ general frustration and confusion evident throughout ɘ impact assessment community in Canada.

The result of a combination of the attitudes, perceptions d constraints outlined above has been a very dilute plication of ecological principles and concepts to envi- ɿmental impact assessment in Canada. The so-called ıotgun' approach has prevailed, with blanket but superficial coverage of all elements of the environment, regardless of their relevance to project planning. The following review of more than 30 Canadian environmental impact statements provides more detailed documentation of what the major scientific shortcomings have been.

> *"Guidelines are just an agency covering its ass!"*
>
> *"The use of scientific tools in EIA becomes frustrating because EIA is motivated for nonscientific reasons."*
>
> *"Most people have a great deal of frustration with the bureaucratic delivery mechanisms for EIA."*

4 — A REVIEW OF SELECTED ASSESSMENTS

One of the initial objectives of the project was to determine the extent to which ecological concepts and principles have been applied in environmental impact assessments in Canada. To meet this objective, a review was undertaken of selected environmental impact statements prepared under various government administrations across the country (Figure 4-1; Table 4-1). The review focussed on the extent to which an ecological perspective was evident in the preparation of such reports, and whether project decisions appeared to be influenced by ecological considerations.

This review is unique in the sense that it concentrated on the application of ecological principles and concepts in impact assessment studies. While numerous reviews of environmental assessment in Canada have already been undertaken, they have dealt with other topics such as assessment techniques (e.g., Coleman, 1977), legal aspects (e.g., Alexander, 1976; Emond, 1978), scientific shortcomings (e.g., Efford, 1976; Rosenberg and Resh *et al.*, 1981), and administrative processes (e.g., Anonymous, 1977; Mitchell and Turkheim, 1977; Adams, 1981; Couch, 1982).

It is important to note that the review was undertaken early in the research project. The bulk of the printed material had not been collected and reviewed nor had any of the technical workshops been held by that time. This does not bear directly on the results of the review itself but it does have implications for the interpretation of the results. At the time of the review, it was not apparent what importance should be attached to the use of various ecological concepts in impact assessments. During the course of the project, we modified our thinking on the value and applicability of many of these concepts. As well, we have since identified a number of ecologically related concepts that we feel it is imperative to deal with in every impact assessment. A prime example is the ecological basis for establishing temporal and spatial study boundaries.

In view of the above, we endeavoured to enhance the original review in two ways. First, we re-examined several of the impact statements originally reviewed, in the light of our deeper understanding of the issues. As well, we collected a substantial number of environmental impact statements for other projects in Canada and examined these in a similar fashion (Table 4-2). The discussion of results reflects a combination of the early review and our subsequent look at the ecological substance of impact assessments in Canada.

METHODS

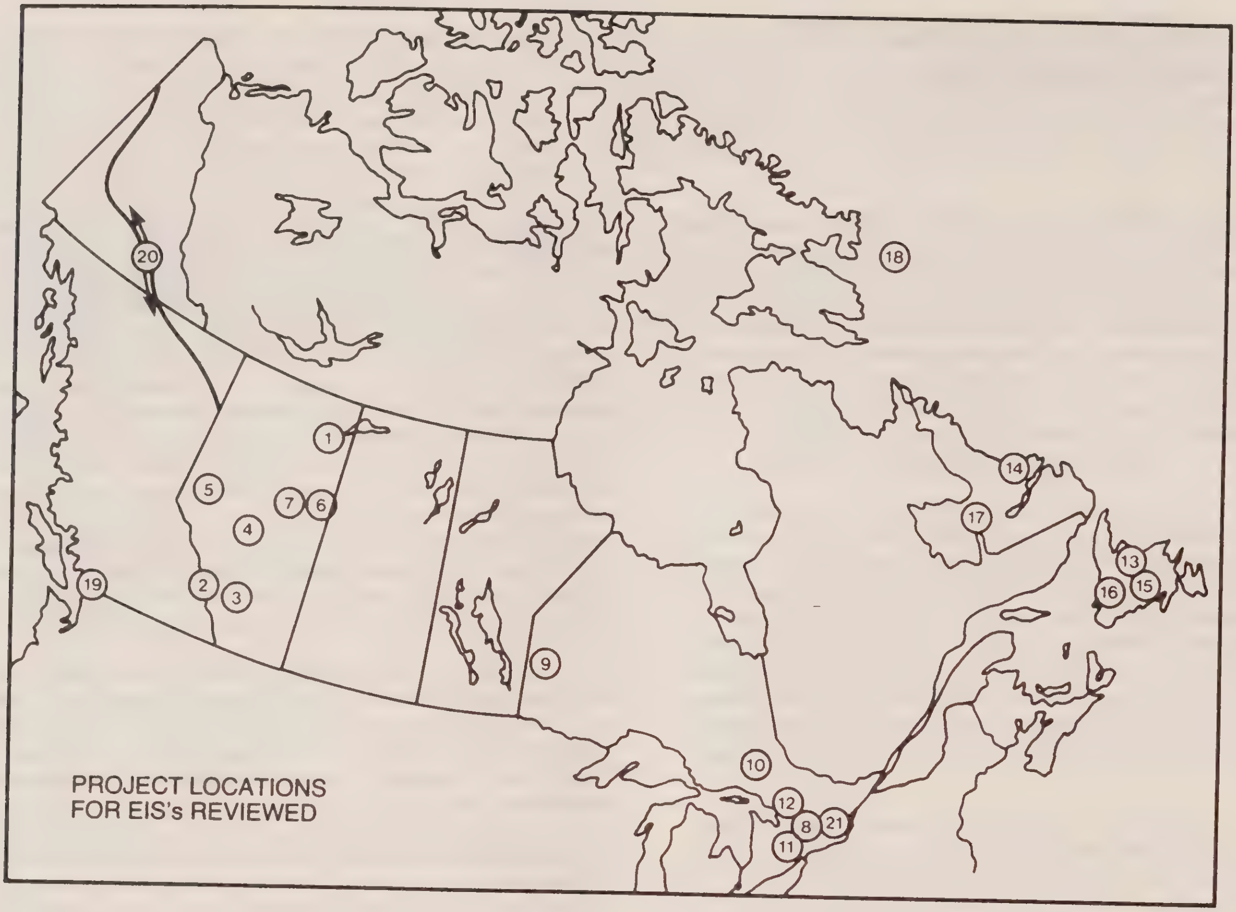
During the fall of 1980, twenty-one environmental impact statements, along with the guidelines provided for their preparation, were reviewed. Assessments conducted according to procedures established by the Newfoundland, Ontario, Alberta and federal governments were selected to reflect a range of project types and differences between policy-based and legislated approaches. Two of these governments administer specific assessment legislation — Ontario, with one of the most comprehensive acts, and Newfoundland which has just recently passed a provincial statue requiring environmental assessments. The legislative mandate for environmental impact assessment in Alberta is contained in a section of the Land Surface Conservation and Reclamation Act passed in 1973. The federal government process operates under a Cabinet policy which specifies the conditions under which an impact assessment is required and how it will be conducted and reviewed (the Federal Environmental Assessment and Review Process).

The majority of the projects reviewed were subjected to what can be considered as a full impact assessment, that is, comprehensive environmental studies contributing towards a final decision on the acceptability of the project. There were, however, some exceptions. The Peace-Athabasca Delta Project was not an impact assessment in the conventional sense since it was only undertaken after the effects of the Bennett Dam on water levels in the delta became evident. However, the study was included in the review since it is a good example of a systems approach and was conducted within the time normally available for impact assessments. In another case, the studies of the Corner Brook Harbour Development were undertaken to fulfill the Initial Environmental Evaluation stage of federal assessment procedures.

During the review of assessment documents, particular attention was given to identifying specific examples where an ecological approach was taken to the design of studies, the collection of data, analytical procedures and the interpretation of results. In addition, in both the guidelines and the impact statements, note was taken of proposed monitoring programmes and recommended mitigation procedures.

Wherever possible, guidelines were examined for their ecological content, although they were not available for all of the projects reviewed. Some of the assessments were conducted under general guidelines designed for all projects (Alberta, Ontario), while others were undertaken according to project-specific guidelines (federal government).

The reviewer had access to decision documents for about one-half of the assessments examined. In some cases the assessments were formally evaluated within the context of larger review and licensing procedures (Alberta) while others were reviewed by agencies established specifi-



1. PEACE-ATHABASCA DELTA PROJECT
2. LANGDON-PHILLIPS PASS TRANSMISSION LINE
3. AGROCHEMICAL COMPLEX EXPANSION
4. KEEPHILLS THERMALELECTRIC STATION
5. FOOTHILLS GAS DEVELOPMENT PROJECT
6. COLD LAKE OIL SANDS PROJECT
7. ALSANDS OIL SANDS PROJECT
8. HIGHWAY 89 ROUTE LOCATION STUDY
9. INTEGRATED FOREST PRODUCTS COMPLEX
10. TEXASGULF CANADA MINE EXPANSION
11. BRADLEY-GEORGETOWN TRANSMISSION LINE ROUTE
12. LOWER MUSQUASH RIVER HYDROELECTRIC DEVELOPMENT
13. UPPER SALMON HYDROELECTRIC DEVELOPMENT
14. KITTS-MICHELIN URANIUM PROJECT
15. HINDS LAKE HYDROELECTRIC DEVELOPMENT
16. CORNER BROOK HARBOUR DEVELOPMENT
17. LOWER CHURCHILL HYDROELECTRIC PROJECT
18. EASTERN ARCTIC OFFSHORE DRILLING – SOUTH DAVIS STRAIT PROJECT
19. ROBERTS BANK PORT EXPANSION
20. ALASKA HIGHWAY GAS PIPELINE – (YUKON PUBLIC HEARINGS)
21. ELDORADO URANIUM HEXAFLUORIDE REFINERY

FIGURE 4-1 NAMES AND LOCATIONS OF PROJECTS FOR WHICH ENVIRONMENTAL IMPACT STATEMENTS WERE FORMALLY REVIEWED

Table 4-1

Details of Environmental Impact Statements Formally Reviewed

	PROJECT NAME[1]	PROJECT DATE OF EIS[2]	LOCATION	PROJECT APPROVAL/STATUS[3]	AMINISTRATION[4]
1.	Peace-Athabasca Delta Project[5]	1973	Northern B.C., Alta., Sask.	completed	Alta., Sask., Canada
2.	Langdon-Phillips Pass Transmission Line	Aug. 1979	Southwestern Alberta	partially approved	Alberta
3.	Agrochemical Complex Expansion	July 1980	Redwater, Alberta	conditionally approved	Alberta
4.	Keephills Thermalelectric Station	Oct. 1979	Edmonton, Alberta	conditionally approved	Alberta
5.	Foothills Gas Development Project	April 1980	South of Hinton, Alberta	under construction	Alberta
6.	Cold Lake Oil Sands	Oct. 1979	Cold Lake, Alberta	in abeyance	Alberta
7.	Alsands Oil Sands	Feb. 1978	north of Fort McMurray, Alta.	in abeyance	Alberta
8.	Highway 89 Route Location Study	Jan. 1979	Keswick, Ontario	partially not approved	Ontario
9.	Integrated Forest Products Complex	Dec. 1976	Ear Falls/Red Lake, Ont.	project abandoned	Ontario
10.	Texasgulf Canada Mine Expansion	Mar. 1976	Timmins, Ontario	approved	Ontario
11.	Bradley-Georgetown Transmission Line Route	June. 1974	Southwestern Ontario	conditionally approved	Ontario
12.	Lower Musquash River Hydroelectric Dev.	Apr. 1979	Orillia, Ontario	application withdrawn	Ontario
13.	Upper Salmon Hydroelectric Dev.	Apr. 1980	Bay d'Espoir, Nfld.	approved	Newfoundland
14.	Kitts-Michelin Uranium Project	May 1979	central Labrador	approval withheld	Newfoundland
15.	Hinds Lake Hydroelectric Project	May 1978	Deer Lake, Nfld.	completed	Newfoundland
16.	Corner Brook Harbour Development[6]	Dec. 1979	Corner Brook, Nfld.	preliminary, no action taken	Canada, Nfld.
17.	Lower Churchill Hydroelectric Project	Apr. 1980	Churchill River, Labrador	conditionally approved	Canada
18.	Eastern Arctic Offshore Drilling — South Davis Strait Project	early 1978	Davis Strait, Eastern Arctic	contitionally approved and drilling undertaken	Canada
19.	Roberts Bank Port Expansion	Oct. 1977	Vancouver, B. C.	scaled-down project underway	Canada
20.	Alaska Highway Gas Pipeline	Jan. 1979	Southern Yukon	approved in principle only	Canada
21.	Eldorado Uranium Hexafluoride Refinery	June 1977	Port Granby, Ontario	location not approved	Canada

[1]Names in this column may be either the title of the project, the title of the EIS, or the title of a government review of the EIS.
[2]Dates given are the month and year of publication of the EIS.
[3]The approvals are those of the reviewing agencies. The status indicated for projects numbered 1, 6, 7, 9, and 16 are not related to the recommendations arising from the assessment reviews.
[4]Administration refers to the government(s) under whose authority the assessment was undertaken.
[5]This study was a cooperative intergovernmental venture established by the Environment Ministers for Canada, Alberta and Saskatchewan, and was an attempt to determine the impacts of low water levels in Lake Athabasca on the Peace-Athabasca Delta.
[6]The document examined for this project was an Initial Environmental Evaluation as defined by the federal assessment process.

Table 4-2

List of Additional Environmental Impact Assessment Reports Reviewed

'roject	Proponent	Date of Report	Administration
IENFAIT EXPANSION PROJECT	Manitoba and Sask. Coal Company (Ltd.)	July 1978	Saskatchewan
LAUDE ORE ZONE EXP. TEST IT	Cluff Mining	December 1981	Saskatchewan
RANE LAKE DEVELOPMENT	Ducks Unlimited (Canada)	March 1981	Saskatchewan
UBYNA 31-ZONE URANIUM RODUCTION PROG.	Eldorado Nuclear Ltd.	December 1978	Saskatchewan
XTENSION OF HIGHWAY 13	Sask. Highways and Transportation	June 1980	Saskatchewan
YDROELECTRIC DEVELOPMENT ON APID RIVER	Saskatchewan Power Corp.	September 1979	Saskatchewan
ROPOSED ROAD, CUMBERLAND OUSE TO AMISK LAKE	Dept. of Northern Saskatchewan	November 1976	Saskatchewan
RANIUM REFINERY IN CORMAN ARK R. M., SASK.	Eldorado Nuclear Ltd.	July 1979	Saskatchewan
982 FACILITIES APPLICATION, ASK. SECTION	TransCanada Pipelines Ltd.	November 1981	Saskatchewan
0kV TRANSMISSION RIGHT-OF-AY,DORSEY-RIEL-INTERN. ORDER, WINNIPEG-MINNEAPOLIS TERCONNECTION	Manitoba Hydro	December 1976	Manitoba
ECTROLYTIC ZINC REDUCTION ANT, BELLEDUNE, N. B.	Brunswick Mining and Smelting Corp. Ltd.	January 1981	New Brunswick
AT ARM HYDROELECTRIC EVELOPMENT	Newfoundland and Labrador Hydro	December 1980	Newfoundland
ELINEATION DRILLING: ABLE ISLAND AREA	Mobil Oil Ltd.	Undated	?

lly for that purpose (Ontario and federal government). e findings and recommendations of the review committee Newfoundland were not available for examination.

't cannot be assumed that the final decision regarding oject approval (Table 4-1) was a reflection of the ecologi- focus of the assessment since social and economic con- rns often have a higher priority with the general public d politicians. However, in the review of the decision ports, particular attention was given to references which icated that an ecological approach, or lack of it, may ve been considered by the review agency. It was impos- le to say whether such information was critical to the al recommendations on project approval or mitigation; wever, if specific references were made regarding an ological perspective, then it was assumed to have at st influenced the thinking of the review agency.

RESULTS AND DISCUSSION

No attempt was made to rank the weaknesses and strengths of the assessments on the basis of ecological and broader scientific perspectives. While a wide variation in the application of ecological principles was evident, it is possible to characterize the quality of the impact assessments examined with the following generalizations.

Guidelines

It appears that assessment guidelines are largely responsible for the sectorial, inventory-style approach so often taken to describing the environment. Guidelines have commonly consisted of an all-inclusive table of contents for an

environmental impact statement. Many sets of guidelines made passing reference to various ecological concepts that might be considered in an assessment; examples include primary productivity, succession, assimilative capacity, diversity, indicators, bioaccumulation, resilience and stability, energy flow, and nutrient cycling. However, such references were seldom accompanied by any further direction or any indication of the importance or relevance of these concepts to the overall assessment.

Interestingly, the relationship between the quality of the guidelines and the quality of the environment assessments, from an ecological point of view, was not always direct. We found examples where some of the better guidelines were followed by ecologically inadequate assessments (e.g., Bradley-Georgetown Transmission Line Route), as well as cases where rather sketchy guidelines were issued, but fairly comprehensive impact assessments followed (e.g., Kitts-Michelin Project).

Boundaries

Most impact assessments provided adequate descriptions of the spatial extent of the project and the limits of the study area. Beyond this the subject of boundary setting, especially temporal and spatial limits in an ecological sense, received no further documentation. While the assessment practitioners may have grappled with some of these boundary issues in planning the studies, the rationale for setting them was seldom included in assessment reports.

Scoping

We have yet to find an environmental impact assessment in Canada that documents the use of a scoping exercise early in the process to focus the assessment on the environmental attributes of principal concern. The norm remains to have a look at everything, at least superficially, regardless how insignificant to the public or to decision-makers.

In spite of this generalization, some assessments have effectively incorporated some process of elimination, albeit part-way through the studies, to focus the scientific efforts. Notable examples include the environmental assessments for the South Davis Strait Project (Imperial Oil Ltd. *et al.*, 1978) and the Upper Salmon Hydroelectric Project (Newfoundland and Labrador Hydro, 1980a).

Significance

In some impact assessments, proponents failed to indicate clearly the significance or importance of the predicted impacts. In others, impacts were qualitatively described in their temporal, spatial, and magnitude contexts but seldom were these descriptors defined. A few environmental impact statements have attempted to define various categories of impacts, but these have provided little in the way of operational direction or clarity for the decision-makers. As examples, consider the following definitions extracted from various impact statements:

> "*Major impacts — impacts of great visual or ecological consequence and which may be regional or long-term in nature. Such impacts may be difficult to prevent or mitigate.*"

> "*Significant impacts are those that require further consideration or action.*"

> "*Significant impacts — impacts that require further action in the form of additional evaluation or implementation of environmental protection measures.*"

Our review uncovered only one assessment (Imperial Oil Ltd. *et al.*, 1978) with a framework for impact significance in which the criteria used were predominantly ecological. This framework is described in detail in Appendix C.

Baseline Studies

This term is currently used as a catchall phrase to include the entire range of pre-project studies. Unfortunately, the studies are normally limited to descriptive, one-time surveys of all the various components of the environment. Seldom is it clear what the objectives are, what limitations there are on data interpretation or what use is made of the results. Few environmental impact statements were found in which an attempt was made to establish quantitatively the natural spatial and temporal variability of selected parameters; seldom was it even recognized that this was important.

Hypotheses and Experiments

Minimal attention has been paid to the setting of hypotheses and the use of experiments to test them. Most experiments for impact assessments have dealt with laboratory trials on toxicity and animal behaviour (e.g., Eedy and Schiefer, 1977). One example was found where the project itself was being studied in an experimental context. In this case (Newfoundland and Labrador Hydro, 1980a), studies were designed to determine the effects of a hydroelectric dam on local caribou populations.

Populations

Existing environments and projected impacts are most commonly described in terms of information and data at the population level. The universal practice seems to be to estimate current and projected densities or populations of species potentially affected by the project. While the main concerns in impact assessments are usually over the status of species populations, investigators seldom recognize that this level of the ecological hierarchy may present the greatest difficulty with respect to quantitative study and impact prediction.

Habitat

Most assessments make the link between species and the physical environment through habitat. This follows

artly from the population focus of most assessments, but lso because many impacts can be traced from physical hanges, through an alteration of habitat, to an effect on ie species of concern. Unfortunately, these relationships re seldom specified in assessment reports; it is even more nusual for them to be studied.

cological Concepts

Many assessments have ignored several principles of ological theory such as nutrient cycling, energy flow, priary productivity, eutrophication, succession, assimilative pacity, and a host of others. Studies are not normally dertaken to elucidate these concepts, nor do they serve predictive frameworks for assessments. A notable ception is the Peace-Athabasca Delta Project which orporated a two-year research programme aimed at preting effects on faunal populations through knowledge of successional patterns of vegetation communities followa lowering of surface and ground water levels. Another imple is the South Davis Strait Project in which an empt was made to understand the variability of the ual phytoplankton bloom and its importance in sustainsecondary productivity throughout the remainder of the r.

dictions

they are made at all, predictions are more apt to be ie generalizations about the likelihood of certain condi- prevailing during and after project construction, as osed to quantified forecasts which could be subjected erification. The exact meanings of most predictive ments found in impacts assessments are highly sub- to interpretation. However, some assessments cond a substantial number of quantified predictions. Con- the following predictions from the assessment of the ids Oil Sands Development (these have been paraed):

) it was estimated that approximately five moose a year would be lost over the life of the project;

water volumes taken from the Athabasca River were expected to be 2.8 per cent of minimum winter flows;

the levels of sulphur dioxide emmissions could damage lichens and mosses 5 — 10 km from the plant.

ontrast, the following predictions were extracted from issessments (these too have been paraphrased):

it was expected that some of the passerine birds would benefit from increased edge habitat;

emissions of nitrous oxides and sulphur dioxides were expected to have deleterious effects on plant ife;

he impact on the aquatic systems was expected to be small;

(d) the water fluctuation resulting from the project may seriously affect nesting and feeding grounds of water birds;

(e) amphibians and reptiles inhabiting wetland areas would be adversely affected by the project;

(f) terrestrial fauna were expected to be negatively affected through direct loss of habitat.

It is difficult to see how such non-commital predictions could assist the general public and the review agency to assess the nature, extent and probability of environmental impacts, and subsequently come to a reasoned decision regarding the acceptability of the project.

Monitoring

In response to directions given in guidelines, most environmental assessments make some reference to proposed environmental monitoring programmes. The discussions range from one-page platitudinous discourses to specific details on the entire scope of the planned monitoring programme. As an example of the latter, Newfoundland and Labrador Hydro (1981a) devoted considerable discussion to current and future monitoring and research activities related to the Upper Salmon Hydroelectric Development.

Mitigation

Most of the assessments reviewed emphasized the mitigation measures to be adopted to reduce or eliminate undesirable impacts. Major sections of the reports were devoted to the mitigation of impacts or such discussion permeated the chapters dealing with impact prediction. In the majority of the assessments, it was clear that few of the studies undertaken had contributed to the identification of suitable mitigating measures. Most of the measures described included well known mitigation techniques, as well as elements of sound environmental planning and construction practices.

Decision Reports

Decisions on project approval are often based on social, political and economic factors, and secondarily on environmental concerns. Despite this, review agencies often consider the lack of appropriate ecological information as a serious deficiency which may influence approvals. For example, approval on the original proposal for the Roberts Bank Port Expansion was denied partly on the basis of deficiencies in the impact assessment related to the effects of the project on the overall estuarine ecosystem. Similarly, in a very ecologically-oriented report, the board reviewing the impact assessment for the Highway 89 Route Location Study withheld approval for that portion of the route crossing the Holland Marsh wetlands pending further information on the ecological importance of the area and potential effects of the highway.

CONCLUSIONS

It is evident that there has been a wide variation in the application of ecological principles to environmental impact assessment reports and guidelines in Canada. Only a limited number of assessments were based on a comprehensive approach to ecological studies. Most assessment reports included only scattered references to ecological principles, usually in connection with species-habitat interactions, natural succession in plant communities and energy and nutrient transfers in aquatic systems.

In general, impact assessments have lacked a recognizable study design within which ecological relationships could be investigated. Rarely was there a central conceptual or analytical theme to guide the collection and interpretation of data. Individual field studies most often focussed on the current number and distribution of organisms, and they often appeared to have been undertaken in a uncoordinated manner.

The collection of baseline data was almost universally recognized in guidelines and impact statements as the starting point for field studies. Seldom, however, did the approach taken attempt to establish a statistical basis for use in the prediction of impacts and the development of a monitoring programme. Predictions were commonly vague, of questionable value both for decision-making and for studies to test them.

There was no evidence to indicate that the adoption of a more rigorous ecological approach would pose extraordinary difficulties in conducting environmental assessments. The few studies that did involve a comprehensive ecological framework and were based on well directed research programmes were completed within the time normally available for impact assessment studies.

Neither was there any evidence to indicate that review agencies would have had difficulty in relating to ecological data and interpretations presented in impact assessments. Specific ecological information has at times been requested to assist the reviewers in defining the characteristics of the environment potentially affected and the significance of the projected impacts.

5 — EARLY MESSAGES

It is clear from the preceding overview that some major changes are required if a substantial upgrading of the scientific quality of environmental impact assessment is to be achieved. Several general messages in this regard emerged early in the project before all of the technical workshops had been held. These messages pertain not only to changes in scientific and practical aspects of impact assessment but to administrative and institutional aspects as well.

ON SCIENTIFIC AND PRACTICAL ASPECTS

The Need for a Common Standard

A clarification of what is an acceptable ecological basis for impact assessment studies presumably would reduce the current state of confusion and different expectations in this regard . It may not be possible, or even appropriate, to develop a rigid set of minimal standards. However, even agreement on the basic considerations to be accounted for in the design, execution and review of assessment studies would represent a major achievement.

At the same time, it is important to allow those conducting impact assessment studies the maximum flexibility in approach. The diverse nature of development projects and the complexity of natural systems argue against the adoption of a rigid, detailed framework to guide all assessment studies.

The Need for Early Agreement

Given the time limitations imposed on environmental impact assessment, it is important that those people conducting and reviewing assessments discuss as early as possible the basic approach to be adopted. The emphasis must be on maximizing the quality of the work at the outset rather than unduly relying on an adversarial review at the end of the process. This may mean that the consultants would proceed with the studies only after having reviewed the scientific and ecological rationale with the technical advisors of the agency administering the assessment procedures. Hopefully, this would enable the final review process to focus on the importance of the impacts rather than on the acceptability of the supporting studies.

The Need for Continuity of Study

All of the participants in environmental impact assessment must recognize the importance of continued study beyond the production of an EIS. The rationale for baseline studies and impact predictions becomes rather tenuous without some follow-up monitoring to the project. The requirement to measure changes in environmental components once a project is in operation demands a much clearer resolution of those components during pre-project studies. Without some attempt to monitor the actual environmental effects of a project, we will never be able to upgrade our prediction and assessment skills.

The Need for Information Transfer

The pursuit of improvements in the scientific basis for environmental impact assessment would be greatly facilitated if everyone in the Canadian assessment community were aware of the most recent concepts, techniques and approaches as developed by imaginative practitioners and by the research community. It is apparent that the majority of proponents, consultants and reviewers, for whatever reasons, are not keeping abreast of recent progress in the field. As a result, many impact assessments produced in Canada reflect an outdated 'state-of-the-art'. The adoption of common scientific standards will depend to some degree on the success of mechanisms for ensuring that all those involved are well informed of current advances in approaches and methods.

ON ADMINISTRATIVE AND INSTITUTIONAL ASPECTS

Responsibilities of Government Agencies

Because of the diversity of objectives and conflicts of interest involved in environmental impact assessment, it is unlikely that the scientific quality of assessment studies will naturally evolve in spite of the good intentions of many practicing professionals. Agencies administering assessment procedures will have to establish certain basic scientific requirements that are realistically achievable and set out in a clear and concise manner.

Proponents and consultants commonly undertake impact assessments according to the procedures established by different administrations across the country. Therefore, it would be most efficient if a common scientific standard were adopted by all agencies. The proponents and consultants will then be able to organize their approach to impact assessments which reflects these common requirements.

Involvement of the Research Community

A particularly pressing problem in Canada, as elsewhere, has been the difficulty of getting research scientists involved in assessment studies. The general reaction of the

:ientific community in Canada was revealed during a ·cent review of the science policy of the federal Department of the Environment (Dr. J. Tener, pers. comm.). At at time, it was apparent that government scientists were ɔt attracted to impact assessment studies, in spite of ɜpartmental priority, for two reasons: (i) the conviction at the political and time constraints precluded quality ɔrk with consequent limited opportunities for publication professional journals, and (ii) a lack of recognition of :sessment work in career promotion and financial lvancement.

he Need for Co-operation

If major improvements are to be made in the ecological sis for assessment studies, then we must begin to relinish the adversarial nature of the assessment forum and to bstitute a co-operative approach to undertaking environɜntal assessments. There is neither enough time nor ɔney for proponents, consultants and review agencies to gage in major disputes wihch can impede the completion a productive assessment exercise. The need for such coeration was one of the driving forces in the organization the project on which this report is based. It was conered imperative to involve a broad representation from entire range of actors in impact assessment across the ɹntry. The recommendations which are forthcoming in ; report represent an attempt to reflect what those peoconsider to be a practical solution to existing problems.

ıe Need for Communication

'he various groups active in environmental impact essment must establish a basis for communication bet- than reacting from opposite sides of a table at review ceedings. One of the sad realizations from the project ; that the workshops often became a sounding board for :trations and misunderstandings about the need for betscience in impact assessment. A forum for productive :ussion and the exchange of ideas among those adminring, conducting, reviewing and paying for impact əssment studies must be established. Resolution of the cipal difficulties will be slow unless the major participts are aware of more than just the problems inherent in r own responsibilities.

:chanisms for Improvement

'hile it may be possible in the longer term to have new :edural or technical requirements adopted by adminisve agencies, we believe the best chance to achieve e immediate success is through suggested changes to ɜxisting EIA infrastructure — even though the adoption of forthcoming recommendations may, in effect, result in fundamental reconsiderations of objectives and commitments.

As recently reviewed by Couch (1982), assessment procedures in this country have a number of sequential features in common:

(a) a determination whether a project will be subjected to formal environmental impact assessment procedures (sometimes called "screening");

(b) the issuing of guidelines to direct the conduct of impact assessment studies;

(c) the preparation of an impact assessment report;

(d) a public or technical review of the assessment report or both; and

(e) a final decision taken at the political level.

This sequence of events is logical and well established in virtually all administrations. While it represents a reasonably firm structural framework, our assumption is that the elements can be substantially altered such that the process becomes more amenable to a scientific approach.

Very generally, significant scientific improvements will depend upon the *early* adoption of appropriate conceptual frameworks and technical standards to guide the required studies, as well as a recognition of the overriding constraint of time in the design of the assessment programme. This translates administratively into (i) substantial changes in guidelines to establish appropriate scientific criteria and (ii) an expanded focus for the assessment report to reflect the need for ongoing experimentation and monitoring.

Guidelines for all projects should incorporate a basic standard of quality which reflects reasonable expectations from ecological and more general scientific perspectives. Beyond that, project-specific guidelines should include a set of objectives in sufficient detail to ensure a proper focus for the studies with respect to information requirements and scientific credibility.

The process of environmental impact assessment should not end with the production of a report. It is our contention that an EIS must become as much a document of future commitment and responsibility as it is a summary of past and predicted environmental events. Given the relatively undeveloped state-of-the-art in accurately predicting long-term biological consequences of proposed activities, post-EIS monitoring programmes must be undertaken for environmental impact assessment to develop beyond the current rudimentary guessing game. The EIS should incorporate detailed statements of commitment by both government and industrial agencies to follow through with carefully selected environmental monitoring programmes.

Part II

A Basis in the Science of Ecology

6 — SCIENCE AND IMPACT ASSESSMENT

SCIENCE, VALUES AND DECISIONS

Science and Values

"The use of knowledge coming out of the scientific approach is not scientific, it is political. The failure of ecological impact assessment is not being able to generate information that can be used at the political level."

"We are forced to consider not only social impact assessment itself, but the social values attached to ecological aspects and the importance of ecological concerns from a sociological perspective."

Environmental impact assessment in Canada, as elsewhere, is a socio-political phenomenon. It is grounded in the perceptions and values of society which find expression at the political level through administrative procedures of governments. Science is called upon to explain the relationship between contemplated actions and these environmental perceptions and values. Although the views of the general public may not be supported by the findings of scientific investigations, their collective aspirations cannot be ignored. It must be recognized, therefore, that decisions resulting from environmental impact assessments may be based as much on subjective judgements involving values, feelings, beliefs and prejudices, as on the results of scientific studies (Matthews, 1975). Indeed, Carpenter (1980) suggested that decision-makers in general often mistrust expert opinion and are not overly influenced by long-term implications outside of their particular jurisdiction.

It is not surprising that environmental impact assessment has been considered an unacceptable forum within which to rigorously apply the scientific method. The Canadian scientific community also has had reservations in this regard. For example, Schindler (1976), in a scathing journal editorial, suggested that impact assessment studies as then practiced amounted to a scientific 'boondoggle', and their continuation threatened the credibility of environmental science in general. Similarly, Efford (1976), in commenting on the problems of environmental impact assessment in Canada, noted that the objectives established were often scientifically unrealistic. In a major review of selected impact assessment reports, Rosenberg and Resh and others (1981) noted numerous areas in which assessment studies would have to be substantially upgraded to achieve an acceptable degree of scientific credibility.

Much of the early criticism concerning the lack of a scientific basis for environmental assessment was warranted. However, there was often a hint of infallibility in these criticisms — the notion that 'good' science will result in 'good' solutions. Bacow (1980) summarized this misconception with these words — "the 'right' information is out there waiting to be gathered and, once collected, it will help us find the 'right' solution." This attitude ignores the socio-political basis of environmental impact assessment and is partly a reflection of the inexperience of many scientists in dealing with their disciplinary expertise in a social context (Efford, 1976).

A realistic role for science in environmental impact assessment is beginning to emerge. Matthews (1975) argued that the value judgements which permeate nearly all aspects of scientific studies associated with impact assessments are acceptable if they are explicitly stated. Holling (1978) cautioned that scientists have their own biases and dispelled the myth that good scientific studies necessarily contribute to better decisions. He advocated earlier and closer linkages between the applied scientists and policy makers. It is now generally recognized that more scientific inputs to environmental impact assessment will not guarantee the resolution of problems, since the conflict may be over differences in values or beliefs rather than over facts (Bacow, 1980). The challenge for all participants in the process of environmental assessment is to maintain a clear distinction between the objectivity of science and the values of society (Matthews, 1975; Lowrance, 1976).

As is evidenced by the quotations from various workshop participants, the relationship between social values and the scientific focus of of assessment studies is generally recognized and accepted. In the mind of one biologist, impact assessment begins with a series of socio-economic filters which are necessary to concentrate the science required. Thus, applied scientists, having recognized the importance of social values, must focus their efforts on translating these values into appropriate environmental studies.

"I submit that the politicians should be there from the beginning. They should be there to cast their shadows, if you will, of the reality of things."

"You must use value judgements to begin selecting the most important aspects to study."

"In most cases, the first step is to try to decide what the people or the bureaucrats are interested in."

Science and Decisions

A Conceptual Framework — Hammond (1978) suggested that most environmental problems are so complex and involve such unpredictable risks that the scientific community is often unable to agree on the advice that should be given to those with decision-making responsibilities. In his view, the confusion and disagreement among scientists, coupled with the high degree of social concern associated

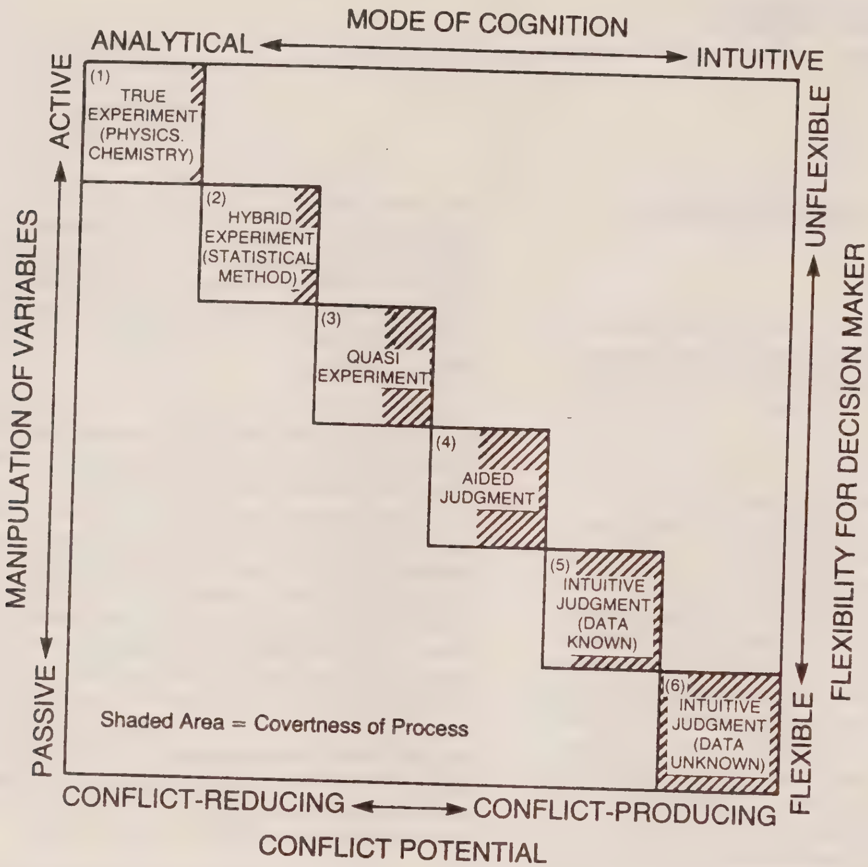


FIGURE 6-1 MODES OF INQUIRY (ADAPTED FROM HAMMOND, 1978)

h many environmental issues, has allowed the value gements of lay people to compete successfully in "the e-for-all of the political arena." This analysis would seem apply to environmental impact assessment.

Hammond (1978) compared the characteristics and con- aints of various modes of inquiry involved in decision- king. His graphical summary (presented in modified form Figure 6-1) helps to place the role of science in impact essment in its proper socio-political context. The classi- experimental approach to scientific inquiry, represented mode number 1 at the upper left, is based on an analyti- approach involving accepted methodologies and control he variables. Although the results are not usually the is for conflict, neither are they of use in solving complex al-environmental problems.

t the other end of the scale, represented by mode num- 6 at the lower right, is the quasi-rational thought that is acteristic of most of us. It involves an uncertain data e, no manipulation of variables, no statistical controls, inconsistent logic rules never made explicit. It has the test potential to provoke conflict but also allows the sion-maker the greatest flexibility in resolving social lems.

Various practical constraints generally prevent the use of mode number 1 as the primary basis for decision-making in environmental impact assessment; nor would it be appropriate since it embodies no social sensitivity. At the other extreme, the use of mode number 6, so prevalent in discussion at public hearings and the testimony of expert witnesses, precludes the substantial reductions in conflict and disagreement which could result from a more analytical approach to the presentation and interpretation of relevant environmental information. The best we can hope for is to invoke mode 4 as the primary basis for decision-making in environmental impact assessment, with limited use of conventional statistical analysis, computer simulation models and a more rigorous approach to the analysis of expert opinion and judgements.

> *"There are two types of general approaches to impact assessment. One, which I would qualify as the 'quick and dirty', involves a grouping together of experts to generate best-opinion guess-timates. The other is an information-based, model-oriented, scientifically established approach. Perhaps a continuum of approaches exists between these two extremes."*

> *"We often must be satisfied with applying professional judgement in assessing ecological impacts."*

"It is important to tailor EIA studies to provide answers at the level needed to make decisions about the project. You would apply a sequence of questions to do this. First, what kind of decision is to be made? Second, what ecological answers are needed? Next, what questions lead to those answers? And finally, what studies address those questions?"

Striking a Compromise — How can a compromise be struck between the subjectivity of value judgements and the objectivity of the scientific approach? In a general sense, we suggest that it is largely a function of the *relative* importance of the role of science at various stages in the sequence of impact assessment activities (Figure 6-2). There seems to be a consensus that initially some direction, explicit or implied, must be given to the scientific pursuits. The logic sequence in providing such direction is considered to involve: (i) impacts perceived to be socially important, (ii) socio-political decisions required, (iii) technical questions posed, and (iv) scientific answers attempted. Thus, the initial major role of value judgements in establishing a focus for the assessment is gradually replaced with a scientific programme of investigation to address the social concerns.

This translation of social concerns into scientific investigations is fraught with moral, conceptual and operational difficulties for many scientists. It is not surprising that dedicated scientists feel professionally constrained when they are expected to focus their expertise solely on social concerns which often change with time. As one workshop participant argued, "Ecologists have special knowledge and should examine environmental attributes they know are important to mankind, whether society at large knows or cares." Furthermore, it is often difficult to conceptualize scientifically the public's perception of an environmental problem: impacts to aesthetic values are a prime example. From an operational sense, population changes in the higher-trophic-level species to which society can relate are difficult to predict with any useful degree of accuracy. The practicing ecologist is often forced to study species at lower levels in the trophic hierarchy and extropolate upwards or rely more on professional judgement and intuition than on quantitative analysis.

Eventually, the pre-project scientific studies must be concluded and the results presented to those responsible for making project-related decisions. At this stage in the process, the importance of social value judgements may outweigh the scientific considerations; it is a question of interpretation. Based on discussions at the workshops, environmental scientists are split on the issue of whether they should interpret the results of their studies or merely present their findings. As Hammond (1978) pointed out, even the most scrupulous scientists often fall into mode 6 (Figure 6-1) when they move from an analytical frame of mind to offering advice to decision-makers. Although the implications can be frustrating to scientists involved in environmental impact assessments, the fact remains that project decisions will reflect some compromise between social aspirations and the results of scientific inquiry.

In theory, the role of the scientist will once again dominate in the design and implementation of post-EIS monitoring programmes. The same range of problems is posed as in pre-project studies; however, there is greater opportunity to apply a quantitative approach in measuring changes than in predicting them.

"What society perceives as important can change as quickly as the weather!"

"You can divide impact assessment studies into two groups. First there are studies on the socially important species; these studies are very difficult but very necessary to do. Then there are the studies on indicator parameters, impacted parameters, or parameters amenable to study; these are easier but are usually less relevant to the public and to decision-makers."

"As a consultant, I try to be objective because proponents want me to say one thing, and government agencies want me to say the opposite. Now I no longer make value judgements."

"Consultants, and others who undertake impact assessments, should proceed beyond the objective reporting of results, and should provide recommendations on the most environmentally acceptable alternatives."

SCIENTIFIC REQUIREMENTS RECOGNIZED

Environmental impact assessment has not been without its critics, including the scientific community. To a great extent, however, the challenge posed by Carpenter (1976) for scientists to accept greater responsibility in setting forth their capabilities and limitations with respect to impact assessment has been met. Members of the scientific community have, for some time, been stressing the need to clarify the scientific basis for assessment studies. Some of the comprehensive publications in this regard provide ample evidence of their recognition of the basic problems, and, in some cases, include advice to assessment administrators. A number of comprehensive reviews on this topic are now summarized.

In 1975, a workshop involving American and Canadian scientists was convened to discuss the biological significance of environmental impacts (Sharma *et al.*, 1976). According to the foreword of the resulting report, "This gathering was the first of its kind and has initiated a thought process in the community of scientists involved with environmental impact assessment that should be of benefit to all concerned, be they from government, industry or the academic community." The individual papers focussed on a variety of topics including temporal and spatial constraints, the need for more statistically valid analyses, the potential use of simulation modelling and the state-of-the-art limitations in ecologically oriented studies. One of the Canadian contributors focussed on the lack of realistic scientific objectives, the misuse of data and the difficulties of accurately predicting environmental effects (Efford, 1976).

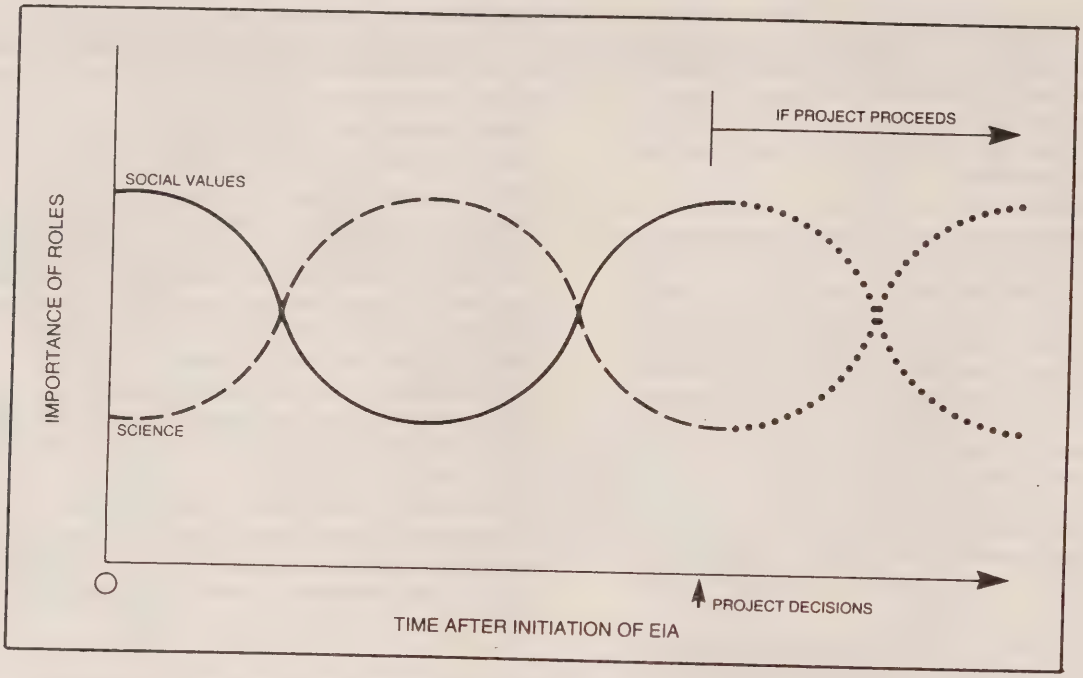


FIGURE 6-2 THE RELATIVE IMPORTANCE OF THE ROLES OF SCIENCE AND OF SOCIAL VALUES IN THE PROCESS OF ENVIRONMENTAL IMPACT ASSESSMENT

ı an excellent discussion on the scientific basis for the :ed States National Environmental Policy Act (NEPA), penter (1976) made the following comment:

At this time, in assessing the progress and future of ıe Act, it is important that those concerned do not 'eoccupy themselves with continued refinement of 'ocedure to the exclusion of examining the state of :ientific knowledge. Otherwise, an elegant administra-/e implementation of a keystone national policy may ɜ so inadequately supported by facts and reasoning at the original objective of placing the full fair weight environmental values on the decision-making scales lost."

ɜ went on to summarize some major problems from administrative and scientific perspectives including:

ı) an unrealistic expectation of legislators and administrators for complete, unambiguous, and verified information;

) the false notion that ecological principles as used so effectively in highly managed systems (e.g., agriculture and forestry) can be applied with equal success in unmanaged ecosystems;

) guidelines which are long on form and short on substance;

) a preoccupation with environmental impacts *per se* rather than some consideration of the rehabilitative prospects for the impacted systems; and

· a lack of recognition of the value of experimentation and monitoring.

In 1977, the Institute of Ecology in the United States published the results of a two-year study designed to "bridge the perceived gap between scientists . . . and those in government agencies responsible for preparing impact statements" (Andrews *et al.*, 1977). In addition to reviewing in detail the general constraints on impact assessment identified by earlier workers, they stressed the need to establish testable hypotheses, set time and space boundaries and adopt a more statistically rigorous approach to baseline studies and monitoring as a basis for verifying predictions. In general, they advocated a greater ecological orientiation for assessment studies including more attention to the recoverability potential of disturbed ecosystems.

The results of two individual efforts, one American (Fahey, 1978) and one Canadian (Ward, 1978), focussed more on the development of an ecological basis for environmental impact analysis within an overall scientific framework. Both authors discussed at length various ecological concepts and principles that might apply in design of assessment studies and they provided examples or case studies to illustrate the utility of such approaches. The advantages of laboratory and field experimentation were discussed as well as the benefits of modelling exercises, both for testing concepts and making predictions.

In a widely recognized book, Holling (1978) developed the rationale behind "Adaptive Environmental Assessment and Management." This approach is an outgrowth of a recognition of the highly dynamic nature of ecosystems and the need to have policy-makers participate in the design of resource management and impact assessment strategies.

The development of a simulation model through a series of workshops involving scientists and administrators is used as an effective means for communication and learning, as well as assisting in research planning and providing some predictive capability. The publication stressed: (i) the high natural variability of most biological phenomena in space and time, (ii) stochastic events and the need to consider risk analysis, and (iii) the resulting futility of trying to predict changes through the inventory approach so common in impact assessment.

The Scientific Committee on Problems of the Environmental (SCOPE) released a second edition of its manual on environmental impact assessment (Munn, 1979), re-emphasizing to a large degree the messages outlined by Holling (1978). As well as reviewing the administrative procedures for impact assessment and the various methodologies available, the volume dealt with the scientific problems of prediction and uncertainty, and with the use of simulation modelling as a working framework for an environmental assessment.

Sanders and others (1980) provided a very comprehensive review of the role of applied ecology in environmental impact assessment. Four general areas were discussed in detail: field monitoring, experimental perturbation studies, laboratory studies, and analytical methods. Considerable attention was given to the need for statistical rigour in the design of baseline and monitoring studies. The limitations imposed by the selection of time and space boundaries were also discussed.

In the proceedings of a symposium of the Ecological Society of America (Anonymous, 1980), various papers dealt with the biological interpretation of environmental impacts. Cairns and Dickson (1980) discussed the vulnerability of aquatic ecosystems to perturbation and their potential for recovery. As well, Hirsch (1980) provided an in depth analysis of the use of baseline studies in impact assessment, covering topics such as the ecological basis, prediction versus monitoring, the constraints posed by natural variability and the problems of linking cause to effect.

One of the more recent major reviews of the scientific implications of environmental assessment is that of Rosenberg and Resh and others. (1981). They and their co-workers rated a number of completed assessments according to a set of ideal characteristics. In so doing, they identified the following shortcomings that are within the control of the scientists involved: (i) ill-defined objectives, (ii) poor research design, (iii) a lack of focus on prediction, (iv) inadequate statistical rigour and (v) poorly written reports. They stressed that environmental monitoring should be undertaken as part of all impact assessments to validate predictions, for mitigation purposes and to provide information of value in other assessments of a similar nature. They also noted the problems posed by the difficulty of obtaining much of the assessment material, including environmental impact statements.

"If we had constructive criticism and quality control on the part of government, then the scientific adequacy of EIA would greatly increase."

PEER REVIEW

The review process in environmental impact assessment should be clearly separated into two distinct aspects: (i) a review of the quality of the scientific and technical work done, and (ii) a public review of the significance or importance of the impacts. These often become confused, with the inevitable result that neither is done well.

While there is little evidence that scientific peer review is regularly incorporated into environmental assessment, the majority of workshop participants were in favour of adopting the practice to the greatest extent possible. In the context of impact assessment, the subject can be reduced to two basic questions: (i) what are the appropriate scientific standards to be applied in studies supporting an assessment, and (ii) how and when should those standards be established and applied?

The Appropriate Standards

It has been suggested that the scientific standards imposed upon basic research are too rigorous for ecological studies in environmental impact assessment. As well, the pressures of politics and time are seen to preclude the adoption of more rigorous scientific approaches to assessment studies. On the other hand, there is a widespread conviction that studies which are found unacceptable through scientific peer review do not provide an adequate basis for assessing impacts. Practitioners are cautioned against radical departures from scientifically acceptable methods in order to conform to the external contraints on an impact assessment. In view of continued debate and disagreement on this topic of suitable standards, it is clear that every environmental assessment must incorporate an early exercise during which all affected parties, especially reviewers, proponents and consultants, discuss and agree on the scientific standards to be applied in the assessment studies. This report provides a basis for establishing those standards for impact assessment in general. Further scientific standards and requirements can be added as considered appropriate for any particular assessment.

Timing of Technical Review

An approach to technical review that will ensure the *timely* application of appropriate scientific standards in ecological assessment studies must be developed. The formal process of scientific peer review, as practiced for refereed publications, may operate too slowly and too late to be the most appropriate approach for EIA. This is not to say that such an approach cannot be used successfully. A recent issue of the journal *Arctic* was devoted entirely to the publication of the results of the Eastern Arctic Marine Environmental Studies, a co-operative industry-government programme established partly for providing data for environmental assessment in general. In the words of Sutterlin and Snow (1982):

" . . .this publication is proof that baseline data collected meticulously and interpreted expertly as part of

›nvironmental impact assessments can indeed with- ›tand the rigorous peer review system demanded by he primary publication system. It is also, perhaps, a :aution against the generalization that environmental npact studies are somehow superficial and less rigor- ›us than other scientific pursuits."

\ great deal of support was given at the workshops for a gramme of technical review in environmental assess- ıt that is active both near the beginning and near the l of the process. This would entail a formal review of the ailed study and assessment plans of the practitioners , proponents and consultants) *before* major field opera- s are undertaken. Technical review would resume when main assessment report is complete, to examine the rpretation and presentation of results. This new empha- ɔn 'front-end' peer review, at the inception and design stages, would help to ensure appropriate levels of scientific integrity in the ecological investigations. Without front-end review, proponents and consultants will continue to run the risk of having to repeat studies in the event the reviewers are unhappy with their design or conduct.

"EIA should be subject to extensive peer review."

"Some time ago, we formed a science advisory committee, composed of retired government and university scientists, as well as senior scientists in our company. Its mandate is to advise on what has to be done in our environmental impact assessments, and how to apply ecological principles."

"We need to poll the best experts we have to undertake peer review of study approaches, methodologies and designs."

7 — THE QUESTION OF SIGNIFICANCE

The question of the significance of anthropogenic perturbations in the natural environment constitutes the very heart of environmental impact assessment. From any perspective — technical, conceptual or philosophical — the focus of impact assessment at some point narrows down to a judgement whether the predicted impacts are significant.

While there exists a myriad of interpretations of the significance of environmental impacts, the perspectives which they represent are equally valid and are not necessarily incompatible. It became evident during the course of the project that the concept of significant impact needs a clear *operational* framework to guide those involved in environmental assessments. Such a framework is proposed and discussed in this section.

In the United States, a judgement of the significance of impacts is used to decide whether a formal Environmental Impact Statement must be prepared according to the NEPA (Andrews *et al.*, 1977). During the workshops, however, the concept was discussed at a more fundamental level — participants were asked to describe a significant environmental impact from their perspectives as scientific professionals. Four basic concepts emerged and are discussed below.

STATISTICAL SIGNIFICANCE

A statistical interpretation of significance represents a relatively value-free approach based on isolating man-induced perturbations (impacts) from natural variation. This notion of significance is well documented in the literature (e.g., Sharma, 1976; Zar, 1976; Buffington *et al.*, 1980) and Christensen *et al.* (1976) gave a conceptual and mathematical interpretation of impact in these terms.

The detection of differences between the variation in project-related variables before and after project initiation is the core of statistical significance. This definition implies measurement to test for change, which is essential from an operational perspective. It also involves the detection of a departure from baseline conditions, which implies that baseline conditions must be known. Finally, its proper interpretation would require the use of acceptable statistical procedures for analysing observed departures from normal variability.

At the workshops, a number of participants stressed the importance of documenting environmental *trends* that are presumed to be linked causally to the project, rather than specific short-term shifts outside of historically defined limits. It was also noted that impacts from a point-specific source often must be evaluated against a baseline which is already following a trend independent of that source, for example, the changes in pH of lakes over large areas as a result of acid rain. Christensen and others (1976) gave an example where the baseline trend in pollution is in a positive direction (i.e., a decline in pollution) which would equally confound the measurement of specific impacts. This continuing variation in natural systems, independent of man's activities, is particularly important in the context of statistical controls for environmental impact assessment studies as reviewed by Eberhardt (1976).

Workshop participants soon recognized some important limitations of a purely statistical definition of significance with respect to environmental impact assessment. Since it is open-ended in time and space boundaries, reference to these elements was considered necessary. In the context of the significance of impacts, the key is not on *what* basis boundaries are established but that they *are* established rationally at an early stage in the assessment of the impacts.

The statistical interpretation of significance ignores the fundamental social focus of impact assessment, particularly the role that assessment should play in the overall project planning and decision-making processes. In other words, the idea of statistical delimitation of project-related impacts does not include any ranking of impacts by priority.

> *"An activity which causes a change to occur which falls outside the observed limits of natural variation and/or a change in frequency of occurrence has a significant impact."*
>
> *"A serious perturbation is any one that I can detect!"*
>
> *"Statistical significance is really the only quantifiable type of significance in an EIA."*

ECOLOGICAL CONCERNS

This is probably the most difficult interpretation of impact significance on which to develop a consensus. There was no general agreement on a definition for significant environmental impact from a purely ecological perspective. Proposed definitions have ranged from specific concerns such as loss of critical breeding habitat, local extinction of species and reduction in primary productivity, to more general but less definitive concerns including loss of ecosystem stability, exceeding tolerance limits, and reduction in assimilative capacity. Most of these definitions contain inherent value judgements, require the existence of some non-biological standard against which to interpret the severity of the impact, or have supply and demand implications.

here are, however, some underlying themes which ear to be fundamental to a consideration of ecological ıificance. First, it may be argued that ecosystems have ntrinsic value; they are ascribed a value in the context ıe extent to which they are used or required by man. ıittedly, this may be an overly restrictive view of ecolog- significance. Yet, the conservation ethic expressed by general public in the environmental impact assessment :ess can most often be traced to a concern for the con- ɘd welfare or survival of people.

ıe second major theme relates ecological significance ıe irretrievable loss of ecosystem components within :ified time and space boundaries. Examples of this, in ɘasing biological importance, include the loss of a ılation, a reduction in genetic variability (gene pool), or oss of a species. As Cooper and Zedler (1980) noted, lestruction of a population can result in the loss of gen- naterial that may have great survival value for the spe- or that may have great value in plant or animal breed- ınd improvement. Time and space limitations must be ısed to separate anthropogenic losses from normal ıtionary processes. Embodied in this theme is the n of stewardship of nature which philosophically may ontradictory to the theme that ecosystems have no sic value.

like the loss of a gene pool or a species, which is ute, the significance of the loss of a particular popula- nust be qualified according to certain time limitations. limitations (recovery times) are seldom discussed in letail in environmental impact studies. The literature our limited understanding of compensatory ınses of populations under stress, even of commercial species which have been extensively studied and ged for some time (Buffington *et al.*, 1980). Indeed, opulation focus for environmental impact assessment be the result of biologists transferring concepts of ation dynamics and maximum sustained yield from es and wildlife management (Sharma, 1976). On the hand, it may be a reflection of the general level of awareness and interest in certain species, the so- "representative and important species" (Christensen 1976).

loss of a population or species may imply an irrevers- ıange in the structure of an ecosystem; however, as d out by Buffington and others (1980), "It is not cer- ɔw many species can be lost, nor how their role can ıaced by species already in the community picking function, without risking collapse of a community." lea of the functional integrity of an ecosystem was by a number of workshop participants as another etation of an ecologically significant impact. How- ıe concept of function often implies the organization :ies at the more complex community and ecosystem ınd, not surprisingly, discussions relating impact sig- ce to changes in ecosystem functioning were often ɘd in generalities such as a disruption of the food a simplification of complex systems or changes in ative capacity.

ɘ was some general support for the idea that s which result in irreversible reductions in primary productivity (the concentration of energy through the production of organic material) should be considered as potentially significant since it represents an erosion of one of the primary life support systems for species at higher trophic levels. Some of the literature on the biological significance of impacts (e.g., Longley, 1979) also reflects this focus on reduction in primary productivity. Unfortunately, neither the literature nor the workshop participants provided any guidance on how rigorously this definition should be applied; for example, is *any* reduction in primary productivity to be considered as significant? Certainly in marine and aquatic systems primary productivity is related to phytoplankton blooms which are so variable under natural conditions that only gross man-induced changes can be detected (Anonymous, 1975). It seems clear, however, that a reduction in primary productivity is one area in which the effects of incremental losses are to be guarded against, especially as they may affect the functioning of aquatic ecosystems.

"All or any impact that tends to reduce production of a desirable species is serious."

"If you accept first of all that a decrease in primary productivity is a significant negative impact, then I think that it strengthens your case."

"I consider a significant negative impact one which irreversibly destroys an ecosystem, or destroys it beyond its ability to self-correct."

"There are three issues involved when considering the capability to evolve in impact significance. One is the immediate survival of the population. The second one is the persistence of vigour and evolutionary adaptation of a population in the face of a changing environment; in other words, the adaptability already within the population. The third one is the continued creation of evolutionary novelty."

SOCIAL IMPORTANCE

Any consideration of the significance of environmental effects must acknowledge that environmental impact assessment is inherently an anthropocentric concept. It is centred on the effects of human activities and ultimately involves a value judgement by society of the significance or importance of these effects. Such judgements, often based on social and economic criteria, reflect the political reality of impact assessment in which significance is translated into public acceptability and desirability. Some authors (e.g., Andrews, 1973; and Buffington *et al.*, 1980) preferred to separate the concept of significance of impacts from public acceptability, while others such as Longley (1979) and Cooper and Zedler (1980) equated the two. In the words of Longley (1979), "Significance is a determination that links estimations of magnitude made by impact assessment analysts with environmental policies."

In this context, the ecological implications of a proposed development usually get translated into effects on physical and biotic resources valued by man for commercial, recreational or aesthetic purposes. From the perspective of an ecologist, more profound changes to the intrinsic structure

and function of natural systems may be involved, but their significance will likely be evaluated by the public in terms of the implications for such resources. In effect, ecologists involved in environmental impact assessment are often required to extend their interpretation of impacts beyond the limits of professional interest and to emphasize those environmental attributes perceived by society to be important.

There emerged from the workshops a number of ideas concerning the public perception of environmental values and their influence in the environmental impact assessment process. These can be characterized as follows:

(a) The first concern of the public with respect to environmental matters is human health and safety. All other concerns are subordinate when Man's health is in jeopardy as a result of proposed development.

(b) The public will have a great concern for potential losses of important commercial species or commercially available production. The reverse would hold true regarding an increase in the numbers of undesirable species.

(c) Society can be expected to place a high priority on species of major recreational or aesthetic importance, whether or not they support commercial activities of any consequence.

(d) Special interest groups will usually gain broad public support in their concern for rare or endangered species on the basis that mankind has special custodial responsibilities regarding their preservation.

(e) Next to the direct impacts on valued species, the public can normally be expected to be concerned over the loss of habitat as it represents a foreclosure on future production, whether or not the habitat is currently being utilized to capacity.

(f) In all of the above cases, public concern will be heightened in relation to perceived imbalances between supply and demand of species or habitats within a local, regional or national context.

Although some workshop participants felt that this man-centred focus compromised their professional contribution to environmental impact assessment, there was a consensus that, ultimately, impacts would be measured on the yardstick of human values. Any comprehensive definition of a significant impact with respect to environmental assessment must reflect this value judgement.

"In the context of impact assessment, what is really of concern at the decision-making level is the significance to society as interpreted through social and economic values. The question of significance is indeed a social and economic one, and it cannot be confined to what we regard as biologically significant."

"Any definition of a significant impact must incorporate a yardstick of human values."

PROJECT IMPLICATIONS

Both the workshops and the literature (e.g., Christensen *et al.*, 1976) have suggested that impacts of any magnitude can be deemed insignificant if they are not considered in making project-related decisions. Fundamental to this concept is that one of the prime purposes of environmental impact assessment is to present relevant ecological information for consideration in project planning. We might consider this project perspective of impact significance to be the 'bottom line' in environmental assessment. In fact, it embodies the previous three concepts by providing the unifying linkage with the assessment itself. In other words, an impact might be considered significant from the perspective of project decisions if it represents a statistically significant change in a socially important environmental attribute, that is either directly or indirectly (through ecological linkages) caused by the project in question.

"In the context of impact assessment, the only changes that are significant are those biological changes that relate to the decision-making process, pertaining to the design, operation, timing, location, etc., of a project."

"One of the first levels of a significant impact is to identify an impact, which is usually strictly physical, that is going to put a severe limitation on the viability of the project."

"Any impact, the assessment of which results in modifications to the project, is significant."

TANGIBLE DIRECTIONS

A short synopsis of what, in our view, constitutes a significant environmental impact is now presented. The following statement rests on the assertions that (i) environmental impact assessment should contribute to informed decision-making, and (ii) a comprehensive definition of significance is required to help focus the activities of all parties involved, particularly those who plan and undertake assessment studies.

Within specified time and space boundaries, a significant impact is a predicted or measured change in an environmental attribute that should be considered in project decisions, depending on the reliability and accuracy of the prediction and the magnitude of the change.

This statement holds a number of implications for the impact assessment practitioner who adopts it as a basic framework for impact significance. The following discussion will outline what these implications are and will show how dealing with these implications can improve the efficiency of environmental assessment.

Time and Space Boundaries

The statement initially points out the need to establish temporal and spatial boundaries when considering the sig-

ance of an impact. Examples of the various criteria opriate for setting such boundaries are discussed else- e in the report; the main point is that boundaries *must* learly and rationally established early in the assessment ess. While boundaries serve other purposes such as ing the spatial extent of study areas and the probable tion of impacts, they are necessary for providing the ext within which impact significance can be judged.

dicted or Measured Changes

ally, there are two major phases in the impact assess- process at which project decisions are made. The first e involves decisions regarding project approval and litions on that approval, and these decisions are based *redictions* of change. The second phase relies to some nt on a reasonable degree of flexibility in project design operation and decisions made during this phase (after ct start-up) are normally based on actual *measure- s* of change. Such decisions are often directed at ges in operation to achieve better emission control or ges in design to mitigate undesirable effects.

us, in adopting this framework for impact significance, ssessment practitioner may consider an impact signifi- at the time it is predicted, *or* once it is detected follow- roject initiation. In some cases, a change may appear gnificant only after a project is in place; reasons for this de:

) the prediction was wrong, and the change is actually larger than expected;

) the environmental attribute was not expected to be affected by the project, and hence no impact prediction was made; and

) changes in the environmental attribute were considered unpredictable under the particular circumstances and the project was studied in an experimental sense to see if changes actually would occur.

isideration in Project Decisions

y information collected or predictions made that have relevance to project decisions are inconsequential to nvironmental impact assessment of that project. In ting our framework for impact significance, the assess- practitioner should judiciously concentrate his assess- efforts and funds on environmental attributes that will have a bearing on project planning and that will be s in the public forum.

s is not to say that the scientific community itself d not add professional concerns to the public debate. y be argued that the scientists have a duty to do so. ointed out by a number of workshop participants, ists have special knowledge and insight that may them to recognize potential impacts of importance to y that might go unnoticed by the general public.

ay be more scientifically expedient to examine surro- or proxy environmental components that can indicate the state of the variable of interest. However, those designing assessment studies must constantly remind themselves that predictions and recommendations in impact assessment reports will have the greatest influence on project decisions if they reflect a focus on changes in valued ecosystem components.

Predictability and Magnitude

The reliability of the prediction should have a bearing on whether a predicted impact is considered significant. In our view, the significance of quantitatively predicted impacts should be determined partly on the basis of the confidence and probability limits of the predictions. In the case where only generalized and qualitative predictions can be made, decision-makers may wish to consider potential impacts as significant until more reliable information indicates otherwise (Andrews *et al.*, 1977).

Our statement suggests the obvious in that the magnitude of an impact has a bearing on its significance. There are a number of considerations with regard to determining what level of impact should be considered significant. For example:

(a) Many environmental variables have stability envelopes within which they commonly fluctuate, and if such variables are forced beyond the limits of the envelope, they may assume quite different or unknown trajectories in time (Holling and Goldberg, 1971; Holling, 1973). In these cases, variables which are predicted to move outside their normal stability limits might be considered as significant impacts, while small shifts within the envelopes might be considered insignificant. Use of this approach is limited to our knowledge of stability envelopes as supported by empirical evidence.

(b) Some important variables may be critically affected by small shifts in other variables. For example, a small downward shift in dissolved oxygen concentration in a lake may be the driving force that causes the demise of the resident trout population.

(c) The concept of "set value" (Andrews *et al.*, 1977) has direct application to determining impact significance on the basis of magnitude. Examples of these values include air or water quality standards, land use plans or other statutory environmental goals. If a variable is predicted to exceed, or is measured in excess of, a set value, then presumably the impact would be considered significant.

(d) The supply or abundance of an environmental attribute may be critical in determining the significance of an impact on that attribute. In brief, if the amount of an environmental attribute destroyed were large compared with the amount or supply of that attribute (in a local, regional, national or global context, depending on the requirements of the analysis and the boundaries established), then the impact may be considered significant (Cooper and Zedler, 1980). It is clear that the boundaries in this context must be

established early. Otherwise, the results of the analysis can be manipulated as desired by adjusting the boundaries.

(e) The resource allocation approach as suggested by Sharma (1976) for allocating the maximum sustainable yield of fish populations among competing uses, may have application in some cases. In such cases the impact would be considered significant if it used up more of the resource than had been allocated for impact purposes.

SUMMARY

A full discussion of impact significance as presented in this section is important for two reasons. First, the term is used imprecisely in environmental impact assessments. Yet, it is often used in contexts where a clear meaning is necessary. The foregoing analysis attempts to clarify the various elements inherent in the term *significant impact.*

The second reason is that the various participants in environmental assessment, especially those who design, undertake and evaluate the impact studies need guidance in many aspects of the assessment including conceptual approaches, attainable objectives, scientific limitations and public expectations. This discussion has shown how a rigorous regard for the meaning of the significance of impacts can begin to provide that guidance.

8 — SOME FUNDAMENTAL CONSIDERATIONS

LIMITS AND CONSTRAINTS

> *"The answer you get, or the effect you perceive, is going to depend on the boundaries you set."*
>
> *"If we pick the right boundaries, we have a better chance of addressing what's going on in the proper scale."*
>
> *"I would suggest that the boundaries you choose depend on the questions you ask."*
>
> *"If you are to approach a problem, you have to conceptually and/or physically describe some kind of boundaries which impose conditions on exchange. The results, then, depend on the kind of boundaries you are going to pose."*

In his treatise on resource management and impact assessment, Holling (1978) suggested that the first of three questions of special concern to those involved in such activities relates to boundaries, that is, "How can the problem be bounded or delimited so that it is tractable and manageable?" Whether explicitly stated or implied, the time and space boundaries imposed set the scope and scale of the required studies and thereby determine, in large measure, the limits of interpretation, extrapolation and prediction.

The importance of setting time and space boundaries in environmental impact assessments has been generally recognized by a number of authors (Fahey, 1978; Dooley, 1979; Cooper, 1980; DeAngelis, 1980; Fritz *et al.*, 1980; Hilborn *et al.*, 1980; and Peterman, 1980) and discussed in some detail by others (Christensen *et al.*, 1976 and Sanders and Suter, 1980). The topic was also pursued at length during some workshops, suggesting it is an area which has been given considerable thought. Few participants failed to recognize the establishment of spatial and temporal limits as a critical early step in impact assessment although it became obvious that these are often assumed rather than stated.

It is clearly indicated in the writings and was reflected in the workshop discussions, that usually more than one set of boundaries will apply in an impact assessment. The bounds of the various sub-problems identified in an overall assessment project would each be set according to different criteria and the spatial and temporal limits so established will not always be common to all sub-problems.

Like many other aspects of impact assessment, the setting of boundaries represents a trade-off, in this case involving (i) the constraints imposed by political-social-economic realities (administrative boundaries) (ii) the temporal and spatial extent of the project (project boundaries), (iii) the time and space scales over which natural systems operate (ecological boundaries), and (iv) the limited state-of-the-art in predicting or measuring ecological changes (technical boundaries) (Figure 8-1). It is important to distinguish between these categories of boundaries since some are under the control of the investigators while others are relatively fixed, for example, by the current state of knowledge in relevant branches of science and technology.

Administrative Boundaries

The process of environmental impact assessment itself poses certain boundaries which are not related to science but which may severely reduce the opportunities to adopt a more scientific approach to impact assessment. These political, administrative and economic constraints represent the first level of study boundaries which should be considered in an impact assessment.

Spatial boundaries may be imposed owing to jurisdictional limitations (i.e., political boundaries) as well as the manpower and money allocated for the assessment studies. These latter constraints also may affect the time available to carry out the assessment. It is a truism that in environmental impact assessment, there is never enough time to undertake the required studies in sufficient detail. Natural systems are complex in structure and function, the complete understanding of which represents a time and money sink of the highest degree. Those responsible for initiating impact assessment studies can help to alleviate this serious time boundary in three ways:

(a) increase the time available by starting assessment studies as early as possible in the project planning process;

(b) make more efficient use of the time available by careful attention to study design; and

(c) continue the studies after project initiation to allow for a continuity in information.

It goes without saying that all those participating in environmental impact assessment *must* strive to reduce the constraints posed by these administrative time and space boundaries to a minimum. Having done that, the impact assessment must be conducted on the basis that the non-scientific limits are explicitly stated at the outset and accepted by all parties.

Project Boundaries

The time horizon and physical extent of project activities normally are readily defined, and details of these limits usually are embodied in a description of the project. The spatial bounding of projects, while sometimes an intricate exer-

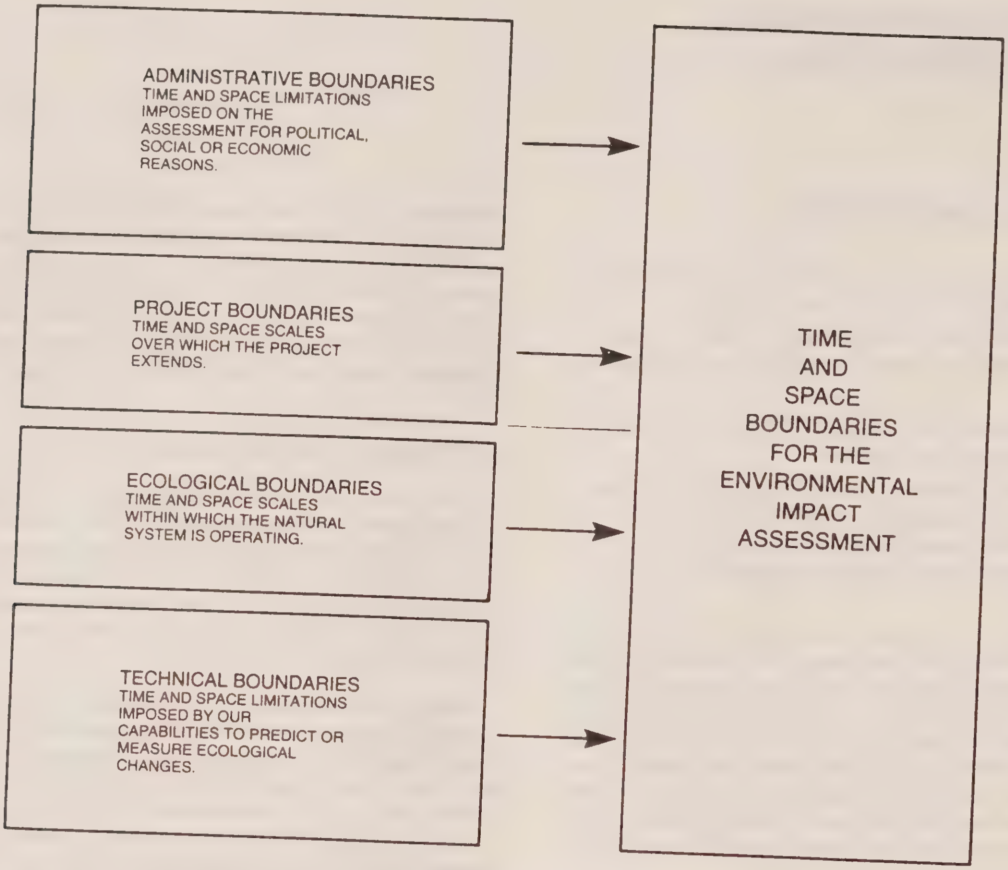


FIGURE 8-1 TIME AND SPACE BOUNDARIES IN ENVIRONMENTAL IMPACT ASSESSMENT

:ise, is usually much more definite than temporal bounding. Vhile some projects can be considered virtually permanent e.g., industrial facilities or transportation schemes), others nay have relatively indeterminate longevity (e.g., off-shore etroleum exploration activities or pest control prorammes). In any case, these limits invariably become djusted to account for other determinants of boundaries s described below.

"Those tankers could go to any one of about seven different places. In approaching the environmental assessment task, do you extend your thinking about the physical environment along the whole length of each of those tanker routes?"

"The time boundary for an impact assessment is often fixed by the proponent on the basis of the 'urgent need' to develop the resource!"

ounding Natural Systems

Ecological boundaries are, in many respects, the most sive boundaries to be considered in an impact assessnt. Bounding the environment in a physical sense, i.e., ough an examination of physical transport mechanisms, sites of material accumulation and interfaces between physical media, is relatively easy when these characteristics are well defined, such as in rivers, lakes or apparently discrete watersheds. In contrast, setting physical bounds of open systems such as oceanic or atmospheric often requires much more insight on the part of the assessment team.

Although not universally accepted, the principle of setting physical boundaries first, followed by biological bounding, was stressed in many of the workshops. This initial focus on physical characteristics and processes of a system for establishing spatial boundaries was a reflection of the general agreement among workshop participants that environmental impacts should be traced from changes in physical structure or function through ecological linkages to the resulting biotic perturbations.

Ecological time boundaries can be established on the basis of a variety of temporal characteristics of natural systems. Such factors include: (i) the magnitude, periodicity and trends in the natural variation of the variables of interest, (ii) the time required for a biotic response to become evident, and (iii) the time required for a system or subsystem to recover from a perturbation to its pre-impact state.

Because of the overriding influence that ecological time and space scales can have on the nature of impact studies and the interpretability of results, a fuller discussion of this topic is presented later. While these boundaries are probably most important to the ecologist, there is seldom any indication of their having been considered in environmental impact assessment.

"You would set the physical boundaries before you even start looking at the biological aspects. The physical boundaries define where you might want to concentrate your biological study efforts."

"There are lots of external influences which dictate that the space boundaries get stretched beyond those which are recommended on physical grounds."

"One way to view the time boundary is the limits forward and backward for which we have knowledge or will have it."

"Perhaps the time boundary for predictions should not be less than one generation of the impacted species."

Technical Boundaries

The overriding importance of time and space boundaries in the prediction of environmental impacts is succinctly portrayed in Figure 8-2. The interpretation is that we can expect to have reasonable success in predicting short-term, spatially limited changes to individuals or specific populations as a result of direct physical effects. In other words, by combining the results of experimental laboratory and field studies involving the elements on the left side of the gradient scale, it may be possible to quantitatively predict, with a useful degree of accuracy, non-chronic direct impacts.

The technical limitations on our ability to predict ecological change are undoubtedly greater than those on our ability to measure them through monitoring. The latter may nevertheless pose substantial difficulties, especially when sampling programmes must be established over very large areas to account for the high mobility of some pollutants and organisms. Examples of other technical constraints in this regard include problems of access in harsh northern and marine environments, and problems of sampling submarine species (e.g., fish and marine mammals).

"We need very long time horizons to see changes in sluggish variables."

"Impact predictions beyond 20 years are fairy tales!"

The Current Situation

We have observed a serious lack of attention given to the establishment of boundaries in most environmental impact assessments. The common fare is to find a study area definition for which little or no rationale is given, and perhaps some vague allusions to the time scale over which predictions apply (for example, short-term, long-term, or permanent). In support of the general response of workshop participants to this subject, we call for a thorough examination of *all* types of temporal and spatial boundaries applying in an impact assessment, and for their full disclosure, including the rationale, in assessment reports.

Perhaps the best example we have seen yet of a rationale for the spatial study area boundaries in a conventional environmental impact assessment is found in Manitoba Hydro and James F. MacLaren Limited (1976). While this case, like most others, falls short of a thorough discussion of boundaries, it at least recognizes some of the concepts outlined above. The boundaries were first based on technical characteristics of the project (a high-voltage power transmission line) including fixed end-points, desired en route connections with other lines and economic objectives (as short a line as possible). The study area was then more precisely defined on the basis of man-made and natural environmental constraints which included avoidance of: (i) an urban expansion area, (ii) an airport, (iii) a provincial park, (iv) a unique ecosystem recognized by the United Nations' International Biological Programme, (v) agriculturally productive areas and (vi) other environmental factors.

QUANTIFICATION

Measurement Versus Description

From a scientific viewpoint, if environmental impact assessment is to be substantially improved, the present preoccupation with descriptive studies must be largely replaced with a quantitative approach. It is the objectivity inherent in measurement which is one of the earmarks of science. It is only through measurements of environmental variables, and testable hypotheses regarding changes therein, that science can contribute to environmental impact assessment at an applied level. Indeed, adopting an experimental or modelling approach or both of them, wherever possible, would automatically result in a stronger quantitative focus for assessment studies.

Quantitative predictions cannot normally be made, nor hypotheses tested, without a firm foundation in measurement. This is not to deny the role of careful observations and descriptions in environmental impact assessment. The results of well-organized reconnaissance surveys, in conjunction with a review of relevant material, can be particularly important in gaining a familiarity with the project environment, not only for the investigator but also for the general public. However, such descriptive studies should not become an end in themselves, as is too often the case in impact assessments. As Hilborn and others (1980) pointed out, the most detailed inventories of environmental components will not provide any indication of how those components will change in the future. Descriptive studies are relatively inexpensive when compared to the time and resources required to undertake detailed experimental field studies. Therefore, they can be used most effectively in impact assessment to direct and focus the more expensive and longer-term experimental studies by providing a basis for conceptualization and the formulation of working hypotheses.

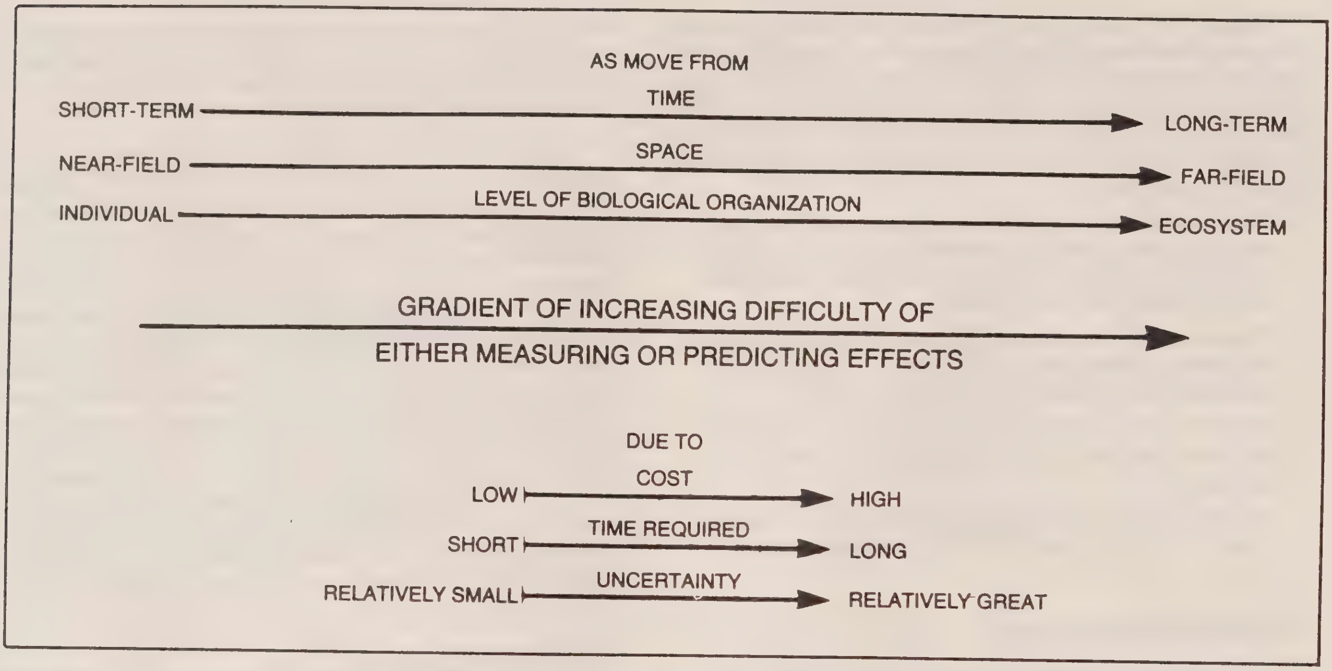


FIGURE 8-2 GRADIENTS ASSOCIATED WITH ANALYZING IMPACTS (AFTER CHRISTENSEN ET AL., 1976)

"There must be a way to make the process more credible. I think the decision-makers treat environmental assessment much more as a strict predictive tool, probably much more a rigorously scientific piece of work than it actually is. We somehow feel naked without numbers. Some of the final products we see are loaded with numbers which do not necessarily mean very much. Yet they have the appearance of a very precise and rigorously scientific approach to assessment. I don't think environmental impact assessment is presented in terms of best professional judgement, which it often is."

"I feel that you can't base an assessment of impacts on just the traditional 'baseline studies'."

"You can only really address problems for which measurements are accessible."

Natural Variability

Most of the scientific and technical problems associated with environmental impact assessment can ultimately be traced back to the natural variability inherent in many physical and biological phenomena. Natural systems, and components of them, are highly dynamic, and patchiness in space and variation over time is common. Often superimposed on random variations are seasonal fluctuations and multi-year cycles. Also, as pointed out by Christensen *et al.* (1976), some variables may be on non-horizontal trajectories in the long term, that is, 'moving baselines.' The field scientists involved in impact assessment face one of their greatest challenges in dealing with such dynamic environmental baselines. Although most ecosystems and populations are perceived to operate within certain stability envelopes (Holling, 1973), it is generally accepted that the time normally available for impact assessment studies precludes anything but an approximation of the natural variability of the important environmental components.

The problems posed by natural variation permeate nearly all aspects of impact assessment studies. It has implications for the establishment of time and space boundaries, the statistical analysis to be used (including the sampling design and intensity) and, thereby, the money and logistics required. Differences in natural variability will influence the choice of variables to be measured and the selection of experimental approaches, and will determine, in large measure, the accuracy of the impact predictions.

The net effects of natural variation on impact assessment studies must be recognized. For example, since natural fluctuations are themselves often large, it may be unrealistic to detect less than a 25 per cent shift in the abundance of populations of many rocky shore species (e.g., Cowell, 1978). Indeed, with highly dynamic variables in ocean systems, even an order of magnitude departure from normal may not be statistically significant (Anonymous, 1981a).

As an example of the practical limitations posed by these problems, consider the report by a committee of the American National Oceanic and Atmospheric Administration (NOAA) (Anonymous, 1974). It was concluded that:

"Within the three-to-five years normally available for marine baseline studies, we can only expect to improve our understanding of the dispersal of pollu-

tants associated with major accidents and attempt qualitative predictions of the effects of such accidents on the general distribution and abundance of important biological components. For many biological indicators, the variability may be so great that we cannot hope to distinguish man-induced, low-level effects."

Statistical Considerations

Problems of sampling design and statistical analysis associated with environmental impact assessment have been examined in detail by some authors (e.g., Eberhardt, 1976; Lucas, 1976; Zar, 1976; Thomas *et al.*, 1978; Kumar, 1980). All of these authors recognized the fundamental need to adhere to acceptable statistical procedures when adopting quantitative or experimental approaches to impact assessment studies. However, natural variability sets limits on reaching this objective. In particular, it hinders the establishment of true experimental controls under field conditions and poses serious constraints on meeting normally acceptable confidence limits.

An ideal impact study design would incorporate replication and controls both in space and time (Green, 1979). However, in the words of Eberhardt (1976), "The experimental approach suffers from the fact that there is no true replication. A pseudo design is proposed, employing pre-operational data on a site and a control area, contrasted to post-operational data on both areas, and substituting replication in time for true replicate areas." In such an approach, the analysis would involve a comparison of ratios of data (Figure 8-3) which accounts for natural changes in measured variables independent of the changes due to the project under consideration. Other authors have stressed the need to have paired sampling stations, that is, equal numbers in both control and impacted areas, in order to allow for an estimate of sampling error within the control area (Lucas, 1976; Gore *et al.*, 1979; Skalski and McKenzie, 1982).

During the workshops, a number of participants gave greater priority to determining environmental *trends* linked by cause and effect to the project, rather than measuring departures from historically defined levels. Some authors also have supported this approach (Lucas, 1976; Hipel *et al.*, 1978). Hipel and his co-workers described in some detail the application of time-series analysis to environmental management problems. This approach would seem to have potential use in predicting and measuring the state of environmental variables that are suspected to follow long-term trends, for example, pH in lakes as a result of acid rain, or slow accumulation of heavy metals in sediments.

Several authors have reported on specific sampling studies which indicate some of the statistical problems. For example, Hartzbank and McCusker (1979) determined the number of replicate samples required at various offshore locations in order to estimate a 50 per cent change in the mean population of dominant benthic species with a probability level of 90 per cent. In some areas, it would require 20-52 replicate samples at each sample location. In another case, Sharp and others (1979) showed how comparisons of indices of natural variability were used to reduce 11 sampling stations to one without seriously affecting the statistical interpretation of the results.

The scientific community has provided some warnings on the potential implications of ignoring proper statistical procedures. For example, a group of marine scientists considering environmental assessment needs for developments on Georges Bank (Anonymous, 1974), cautioned that "a conservative approach should be taken towards additional data gathering projects. Without careful statistical controls sensitive to normal variations in the marine environment, baseline information can prove meaningless and merely divert resources away from more significant endeavours." In another case, researchers studying the results of 39 individual monitoring programmes for three nuclear power plants in the United States (Gore *et al.*, 1979) showed that "field programs may have been inadequate to detect changes, due to infrequent sampling, inadequate number of control stations, little or no pre-operational data, station location changes, sampling gear changes with no overlapping calibration factors or inconsistent reporting of results." In short, a waste of time and money.

"The problem you have with survey data is the variability, and there is no guarantee that, unless you do something very specific, the pre-operational data will be tractable."

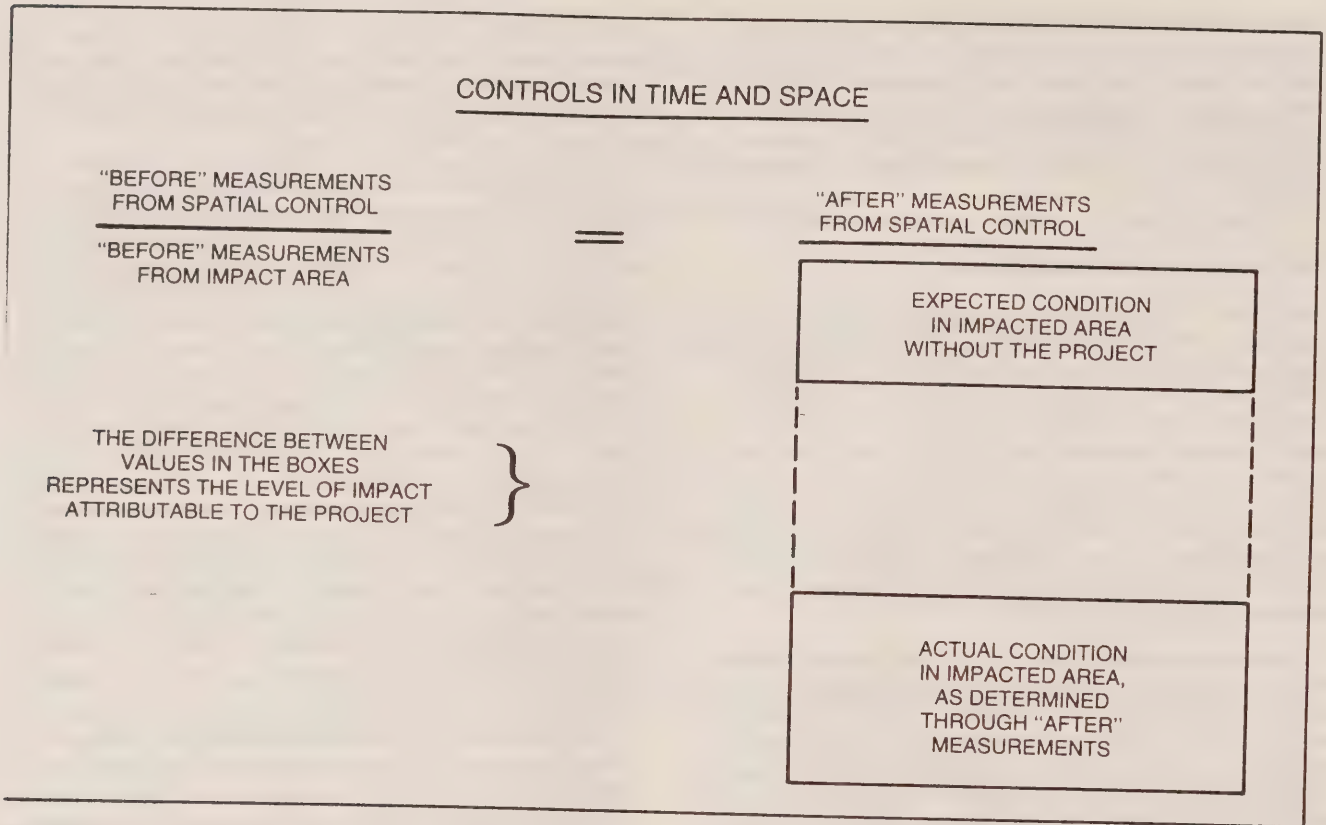
"For the most part, you are only sampling and measuring noise in the ecosystem. There is so much variability that you must have huge sample sizes, and sample over large areas for a relatively long period of time, to be able to pick up a signal."

"The concept of 'long-term mean' is ridiculous — you don't average the data from a number of consecutive years. This is time series data that may already exhibit a trend."

"You must keep the concept of trend in mind as well as the envelope of variation."

MODELLING

There was widespread agreement among workshop participants that conceptual and quantitative modelling are very useful and appropriate scientific tools for impact assessment studies. This view has been well substantiated in many treatises on modelling for impact assessment (e.g., Jeffers, 1974; Gilliland and Risser, 1977; Holling, 1978; Ward, 1978; Munn, 1979; Barnthouse and VanWinkle, 1980; Fritz *et al.*, 1980; Kumar, 1980). Yet our review, and other reviews of environmental impact assessment reports, indicate a limited and sporadic use of either conceptual or quantitative modelling. One can only speculate on the reasons contributing to this lack of modelling in assessment studies. It is certainly not because of a dearth of guidance on how to use these tools in an assessment; the above-noted literature is only a fraction of what is available on this



'IGURE 8-3 CONTROLS IN TIME AND SPACE IN EVALUATING IMPACTS

ubject. Perhaps a general perception that modelling is ery difficult to undertake (which in many cases may be ue), coupled with the general view that adequate assess- ıents can be undertaken without modelling, account for ıis shortcoming.

A ɾnodel can be considered an incomplete or simplified ·presentation of reality (Regier and Rapport, 1977; Barnt- ouse and VanWinkle, 1980). For the purposes of this ·port, we distinguish between two broad (but often ·lated) classes of modelling. The first, conceptual modell- g, is often descriptive in nature. The second, quantitative odelling, is by definition a mathematical exercise, and 'ten fulfills many of the same functions as descriptive odelling, as well as a few other key functions.

"It's been my experience that you can't take a model off the shelf and make it work. And it's unreasonable to expect a proponent to develop a big model."

"We should differentiate clearly between two types of modelling — mathematical simulation modelling, and intuitive modelling, which is conceptual."

onceptual Modelling

It is difficult, if not impossible, to find any written material oral commentary offered at the workshops, which frowns on the early use of conceptual modelling in impact assessment. The list of advantages and functions provided by such modelling is long and includes: (i) identification of conceptual errors, (ii) identification of factors requiring study, (iii) assistance in formulating hypotheses, (iv) organization of ecological relationships, (v) synthesis of ideas, (vi) communication of information, and (vii) identification of potential impacts (Gilliland and Risser, 1977; Holling, 1978; Ward, 1978; Fritz *et al.*, 1980; Kumar, 1980).

We recognize that conceptual modelling can be a very complicated task and fraught with frustation. This is clearly evidenced by the failure of many of our workshops to conceptualize adequately the project-environment interactions during our analyses of realistic but hypothetical development scenarios. Among other reasons, this may have been because of the general difficulty that most discipline-oriented professionals have in thinking in a conceptual, interdisciplinary mode. Also, our workshops did not provide sufficient time or the appropriate resources for the participants to actually develop conceptual models. We believe that under suitable conditions (most of which can easily be fulfilled in any environmental assessment exercise) conceptual modelling can be undertaken successfully and would provide some much needed direction and focus for impact assessment studies.

"We are certainly at the stage now where we can put the conceptual model on the table."

"Models perform the function of showing the areas of our greatest ignorance!"

"Models are teaching tools, and should be incorporated more often into assessment activities."

Quantitative Modelling

Considerably more controversy arose in the workshops over the application and utility of quantitative modelling in environmental assessment. Both the workshop discussions and the publications identify a host of purposes for, and benefits from, quantitative modelling exercises in impact assessments. Some of these include (i) forcing assumptions to become explicit, (ii) formulating and testing hypotheses, (iii) identifying knowledge needs and thus guiding data collection, (iv) forcing careful, unambiguous system description, (v) bookkeeping of data, (vi) organizing concepts and ideas, (vii) testing impact scenarios, (viii) making impact predictions, (ix) suggesting appropriate mitigation, and (x) providing an effective teaching and communication tool (Jeffers, 1974; van Keulen, 1974; Walters, 1975; Gilliland and Risser, 1977; Holling, 1978; Ward, 1978; Ogawa and Mitsch, 1979; Kumar, 1980; Marsan and Coupal, 1981).

Additional advantages of quantitative modelling are that (i) it is highly cost-effective compared to other study tools for impact assessment and (ii) it is a non-perturbing and non-destructive method of investigation (which may be morally important for examining effects on high-profile species and humans). While Pielou (1981) argued that ecological modelling historically may have played too large a role in theoretical and academic ecology, we feel that such modelling, especially when coupled with experimental studies, can and should play a much larger role in environmental impact assessment.

The major cautionary note to be levelled at quantitative modelling concerns its predictive power (Cooper, 1976; Regier and Rapport, 1977; Holling, 1978; Marsan and Coupal, 1981). The general message, which equally reflects the opinion of many workshop participants, is that quantitative models may provide reasonably solid predictions for the physical fate of pollutants and perhaps for some first-order biotic effects which are directly linked to physical changes. However, ecological effects modelling is generally considered to be unreliable for the purpose of predicting impacts.

"You can use models in impact assessment to identify 'limiting factors' and 'critical levels' of species."

"Modelling on a computer takes little time and money in relation to its beneficial aspects."

"The purpose of computing is insight, not numbers."

"In many instances, you have no choice but to use mathematical simulation. For example, if we examine public hazard from an explosion or a fire, you just cannot do an experiment!"

"Most people now say that simulation activities are mostly valuable because they have the power to generate hypotheses."

Recent Applications

Quantitative modelling, especially computer simulation modelling, appears to be used on a somewhat regular basis in certain specific aspects of environmental impact assessments. Many of these applications deal with physical transport mechanisms operating in the atmosphere or in water bodies. For example, computerized slick trajectory models are commonly employed for predicting the movement of accidental oil spills in the marine environment (e.g., Imperial Oil Limited *et al.*, 1978; Norlands Petroleums Ltd., 1978; and Martec Limited, 1980). Another common application is for the prediction of air quality and of the fate of aerially discharged emissions (e.g., Beak Consultants Limited, 1979; Eldorado Nuclear Limited, 1979; and Hatch Associates Ltd., 1981). Finally, quantitative modelling is used regularly to examine hydrological and ecological changes expected to occur in new reservoirs of large hydroelectric developments (e.g., Beak Consultants Limited, 1977; and Thérien, 1981).

While the use of ecological modelling is very limited in environmental impact assessment (except perhaps in predicting impingement and entrainment impacts from thermal power plants), there is a substantial body of experience in the use of such modelling for resource management problems and environmental impact research. Of special significance in this regard is the study approach developed at the University of British Columbia over the past two decades. The approach normally employs two basic elements-computer simulation modelling and interdisciplinary workshops. The modelling exercises are usually a combination of conceptual modelling and quantitative modelling as described above, and as such they reap the benefits of both.

A number of recent publications (e.g., Walters, 1975; Holling, 1978; Hilborn, 1979; Jones *et al.*, 1980; and Truett, 1980) have discussed the successes and failures of numerous case studies in which the so-called Adaptive Environmental Assessment and Management philosophy has been applied. In early 1982, a workshop sponsored by the federal Department of Environment to review applications of, and the future prospects for, the modelling-workshop approach revealed that the approach has been applied in over 60 instances. In spite of some dismal failures, it has apparently been successfully applied to several research planning efforts, resource management and policy analyses, ecological syntheses and environmental impact studies. Of particular importance to this report was the workshop conclusion that the modelling-workshop approach has very broad applicability in the conduct of environmental impact assessments. However, the workshop participants did not present any reasons why the approach has not been more widely adopted in Canada.

PREDICTION

Participant A
"We should be getting away from the idea of impact prediction."

Participant B
"But that's what you guys want!"

Participant C
"I know that's what they want, but they can't have it."

Participant D
"Are you also saying we should get away from assessment?"

Participant A
"Assessment we do want; prediction we don't want."

Participant D
"If we are not going to talk about prediction, we may as well go home!"

(Pandemonium followed)

In the minds of most participants at the workshops, and as generally reflected in the printed material, environmental impact assessment is equivalent to impact prediction — prediction of the changes from baseline conditions as demonstrated by the results of post-development monitoring. The frustrations experienced by the applied scientists in attempting to get a reasonable description of environmental variables during baseline studies often build to a sense of futility when they are faced with the need to predict how these variables will change. As Moss (1976) pointed out, the challenge is not to make predictions, but to make *accurate* predictions, which implies that they can be tested. From this technical perspective, prediction is the 'Achilles' heel' of environmental impact assessment. This was clearly reflected in the workshops by the tendency of most participants to mentally jump from baseline studies directly to monitoring, ignoring the details of the crucial step between the two.

Not surprisingly, our track record in making testable predictions in environmental impact assessment is dismal. The apparent reluctance or inability to make quantitative predictions is probably the combined result of the state-of-the-art in theoretical and applied ecology, the limited use of appropriate experimental and modelling approaches, the limitations imposed by time, money or assessment objectives, and the limited expertise and capabilities of individuals undertaking assessments. In any event, predictions in assessment reports usually have amounted to generalized or vague statements about the possibility of certain conditions occurring. Our critical evaluation of Canadian impact assessments showed that less than one-half included recognizable predictions, and the majority of these were generalizations, the accuracy of which could not be determined.

Canadian impact assessments are not unique in this regard. A recent report of post-development audits of North Sea projects (Anonymous, 1981b) listed a number of vague predictions concerning the effects of oil on seal breeding sites, all from the same assessment:

(a) The oil handling terminal should, however, have no marked effect on the seal populations in the Flow, unless oil was washed onto the breeding sites.

(b) Seals might be affected by the mechanical effect of oil release if slicks of oil were allowed to reach shores during the breeding season when cows and pups are immobile.

(c) Seal populations could be seriously reduced if an oil release took place during the breeding season.

In the same study, an audit of two petroleum handling facilities showed that out of 545 predictions, less than 9 per cent were verifiable. Similarily, Andrews (1973), in reviewing impact assessments in the United States, noted the almost exclusive use of the descriptive approach as opposed to attempts at prediction.

In general, we can expect more accurate and quantitative predictions of project-induced changes in the physical environment since our ability to model physical systems is relatively well developed. However, most predictions of biotic impacts are based on certain assumptions concerning physical changes; in effect, they are second-order predictions. Therefore, predicting even so-called direct impacts in biotic systems involves a much greater degree of uncertainty. Added to the difficulty in predicting long-term, distant impacts at the higher levels of biological oragnization is the overriding constraint posed by stochastic events, which, by definition, cannot be predicted (Moss, 1976), although their influence can be incorporated into simulation models (Hilborn *et al.*, 1980).

Throughout the general discussions at the workshops, the terms 'orders of magnitude' and 'long-term trends' were often used with regard to the determination of impacts in general. These phrases probably convey the level of confidence in prediction held by the participants, given the natural variability of most natural systems, the time and money constraints imposed on most assessments and the limits imposed by their familiarity with the state-of-the-art in predictive theory. This perspective is also expressed by Auerbach (1978) who suggested that "ecologists have an obligation to predict effects quantitatively, at least with respect to duration and order of magnitude."

In spite of the above constraints, there is substantial room for improvement in predicting the biological results of man-induced perturbations within the context of environmental impact studies; our limited capability to predict is no excuse for the current boycott of effort in this regard. The following steps would result in substantial improvements:

(a) Environmental impact assessments should be designed to *attempt* quantifiable predictions, making use of experimental approaches and modelling exercises.

(b) Assessment studies should focus on environmental components which represent the best compromise between predictability and the information needs of decision-makers. We should consciously try to improve our basis for prediction before extrapolating through professional judgement.

(c) Assessment reports should clearly indicate the basis upon which each prediction is made. While such bases may legitimately fall anywhere along the con-

tinuum from firm predictions, through forecasts based on experience or professional judgement, to outright guesses, it is essential that all parties involved in impact assessment have ready access to such information.

"This is one of the places where I think ecologists have been irresponsible. They will NOT do their best evaluation of the 'reasonable high and reasonable low' limits of a prediction, because they say it can't be done. Yet the decision-maker doesn't have that option — he absolutely, unequivocally needs estimates of these limits."

"We can predict that an impact will occur, but we can't quantify it."

"Let's face it — nobody can 'predict' on the basis of a two-year EIA!"

"A lot of people are trying to predict yields from semi-controlled ecosystems such as in agriculture, and they are having difficulty. In uncontrolled ecosystems, where our knowledge is still very imperfect, our expectations for prediction shouldn't get too high."

"I make a separation between an analytical, quantitative equation where you put in numbers and you want the scientific validity to justify what you are doing, versus asking some fisheries biologist with 40 years of experience what he thinks will happen."

"It seems as if the physical scientists are the only ones able to predict with any confidence."

STUDY DESIGN

The scientific studies in support of an environmental assessment should be guided by the need to answer specific questions. The impact assessment practitioner can choose from among a wide variety of study designs and tactics in order to meet his information needs. Examples of such tactics include reconnaissance level surveys, detailed resource inventories, perturbation experiments and studies in support of simulation modelling. The key is to select an efficient mix of studies to fill the knowledge gap. Once particular study types are decided upon, the assessment scientist must apply the accepted scientific standards and procedures appropriate for each type of study.

The particular sequence of steps to be used in any impact assessment is not of critical importance here. In this report we do not present a detailed approach to impact assessment studies; examples of such approaches are already available in the writings (e.g., Holling, 1978; Truett, 1978; Ward, 1978; Boesch, 1980; Fritz *et al.*, 1980; Sanders *et al.*, 1980; Hinckley, 1980; and Rosenberg and Resh *et al.*, 1981). Also, many workshop participants volunteered their personal approaches to impact assessment studies. Any of these approaches may be successfully applied or adapted to a wide variety of assessment studies. We wish to emphasize that the practitioner must appreciate the technical implications of the study design chosen and the utility of the information the study provides. Reconnaissance surveys have their own set of technical requirements and provide different inputs into the overall impact assessment when compared with pilot-scale perturbation experiments. For example, a reconnaissance survey may contribute to the conceptual understanding of the environment and be accomplished in a very short time in a descriptive fashion. On the other hand, the pilot-scale experiment implies a need for rigorous hypothesis testing and statistical validity and probably a great deal more time. In a similar way, the technical characteristics of studies designed to provide input data for simulation modelling may differ markedly from the scientific requirements of implementing a baseline and monitoring programme, which uses the project itself as the perturbation in an experimental context.

It is evident from the literature and from discussions at the workshops that impact assessments often suffer not only from poor technical design of field investigations but also from studies which serve no particular purpose. Hilborn and Walters (1981) discussed a number of reasons why traditional baseline and process studies fail to provide the information needed to predict environmental impacts. They aptly labelled such traditional pre-project environmental studies as 'helicopter ecology.' Ward (1978) agreed with these criticisms in her treatise on experimental impact assessment studies, and she succinctly described two common approaches to environmental assessment taken by some consultants, namely, the 'busy taxonomist' approach and the 'information broker' approach. As mentioned previously, Rosenberg and Resh and others (1981) identified several shortcomings of impact assessment studies that are within the control of the practitioner; specifically, two of these faults are (i) the very superficial nature of the research conducted and (ii) the use of inappropriate types of studies in support of impact prediction. These authors advocated the replacement of surveys and intuition with quantitative experimentation and simulation. In summary, the scientist must use whatever study tools are available to provide the information needed for the impact assessment, whether that information is needed for general understanding of the environment, as a basis for specific impact predictions, or to further the state-of-the-art in impact prediction for similar projects in the future. What must be kept foremost in mind is that each study tool has its own specific scientific and technical requirements and that each contributes to environmental impact assessment in a different way.

Experimentation

"In instances where you have no basic data, I think experimental manipulations are absolutely essential."

"Experiment money is money well spent!"

"You need to use as much experimental design in EIA studies as possible."

"The next step is to develop a set of testable hypotheses that postulate how the planned action affects the important environmental attributes."

The use of laboratory and field experiments has great applicability in environmental impact assessment (Fahey,

1978; Ward, 1978). The classic experimental design, however, can seldom be properly applied to field studies because of difficulties in establishing control sites (Cowell, 1978) and in demonstrating replicability (Eberhardt, 1976). Nevertheless, the use of hypotheses and statistically based designs are sorely needed in assessment studies, even if they will not conclusively demonstrate cause and effect relationships (Gore *et al.*, 1979; Sharp *et al.*, 1979; Fritz *et al.*, 1980; Giddings, 1980).

The testing of hypotheses is fundamental to all forms of experimentation. A hypothesis is usually grounded in a concept or assumption and involves a level of specificity and preciseness beyond that implied by a general question. In the words of Green (1979), as an investigator you must "be able to state concisely to someone else what question you are asking. Your results will be as coherent and as comprehensible as your initial conception of the problem." If an experimental approach for environmental impact assessment were adopted more often, it would lead to a more focussed study effort since the need to establish testable hypotheses forces a refinement in one's thinking. One of the most obvious shortcomings in impact assessment studies is the lack of clear direction; it is more common to pose some vague questions which lead to equally vague answers. The resulting negative influence on impact assessment was clearly stated by Fritz and others (1980) in their development of a strategy for assessing the impacts of power plants:

> "The process of generating and testing hypotheses has, for the most part, been ignored by those assessing impacts of power plants. This failure may account for the relatively inconclusive results produced in environmental assessments and for the controversies that have arisen over estimates of the environmental impacts of power plants."

It would be unrealistic to suggest that all questions posed n an environmental impact assessment could be set in the orm of a null hypotheses so common to statistical nalyses. Rather it is the *process* of refining a generalized uestion into a form which requires a specific, preferably uantitative, answer which is important. For example, the articipants at one workshop, in considering the impacts of proposed dam, started by posing the question, "What vould be the impacts of the dam on the fish resources of he river?" After considerable discussion, they eventually greed that a more appropriate question to guide the study ffort would be, "What percentage of available Arctic char pawning habitat would be lost given a 0.5 metre reduction the water level of the river during the month of September?"

Pre-Project Experiments — Predictions based on the esults of experiments conducted before project commitment can provide a strong scientific basis for influencing ecisions. Laboratory experiments, such as toxicity trials, an be conducted under controlled conditions and the nalysis of results can conform to good statistical practes. However, as explained in some detail by Ward 978), the major problem lies in extrapolating the results field conditions. Thus, in the context of impact assessment studies, laboratory experiments should be conducted in conjunction with, or be guided by, field investigations and modelling exercises.

An example of the use of laboratory studies in an environmental assessment for a Kraft pulp mill in Northern Quebec was described by Eedy and Schiefer (1977). Simulated mill effluent was used in conducting toxicity and behaviour experiments on a number of freshwater fish species. Another type of controlled laboratory study that has application potential in environmental impact assessment is the system microcosm. Briefly, microcosms are artificially created, small-scale models of natural ecosystems. Microcosms have several advantages over field studies including practicality, controllability, replicability and ease of manipulation (Ward, 1978). They can range in size from small laboratory containers to large enclosures. For example, Heath (1979) examined the response of aquatic microcosms in Erlenmeyer flasks to cadmium stress, concluding that the "holistic investigation of such systems is a sensitive and rapid means of assessing stress at the community level of organization." At the other extreme, microcosms of 1700 cubic metres maximum volume have been used in controlled ecosystem pollution experiments (Ward, 1978). The use of controlled ecosystems (microcosms) have also been adopted for research on larvae and juvenile populations of fish (Anonymous, 1980b).

In our opinion, on site pilot-scale perturbation experiments may be the most realistic and productive avenue to pursue in impact assessment studies. These seem to be generally accepted in the engineering field where fully-instrumented test facilities, such as pipeline loops in the Arctic, provide data of direct use in project design. Although there are some examples where it has been effectively used in environmental impact assessment, it offers much greater potential than is now being realized.

Figure 8-4 shows how such pilot-scale experiments can be incorporated into the general sequence of impact assessment activities. Although not directly associated with a particular environmental impact assessment, the Baffin Island Oil Spill Project (BIOSP) is an example of such experimentation. The results should be of great value to all future assessments in the north in predicting the impacts of oil spills on Arctic nearshore marine ecosystems. On the other hand, relatively simple experiments might suffice. For example, as part of the assessment studies for the proposed Alaska Highway gas pipeline, experimental plots were established at locations along the proposed route to test the suitability of various species and fertilizer for a revegetation programme.

> *"I would say very definitely that there is a great need for more experimental studies for EIA. BIOSP is an excellent example."*

> *"There are three kinds of studies I would do for prediction — mathematical simulation, laboratory studies and* in situ *experiments."*

The Project in an Experimental Context — Considering the project itself in an experimental context forces both a recognition of our limited capabilities to predict ecological events and a recognition of the the need to translate the ill-

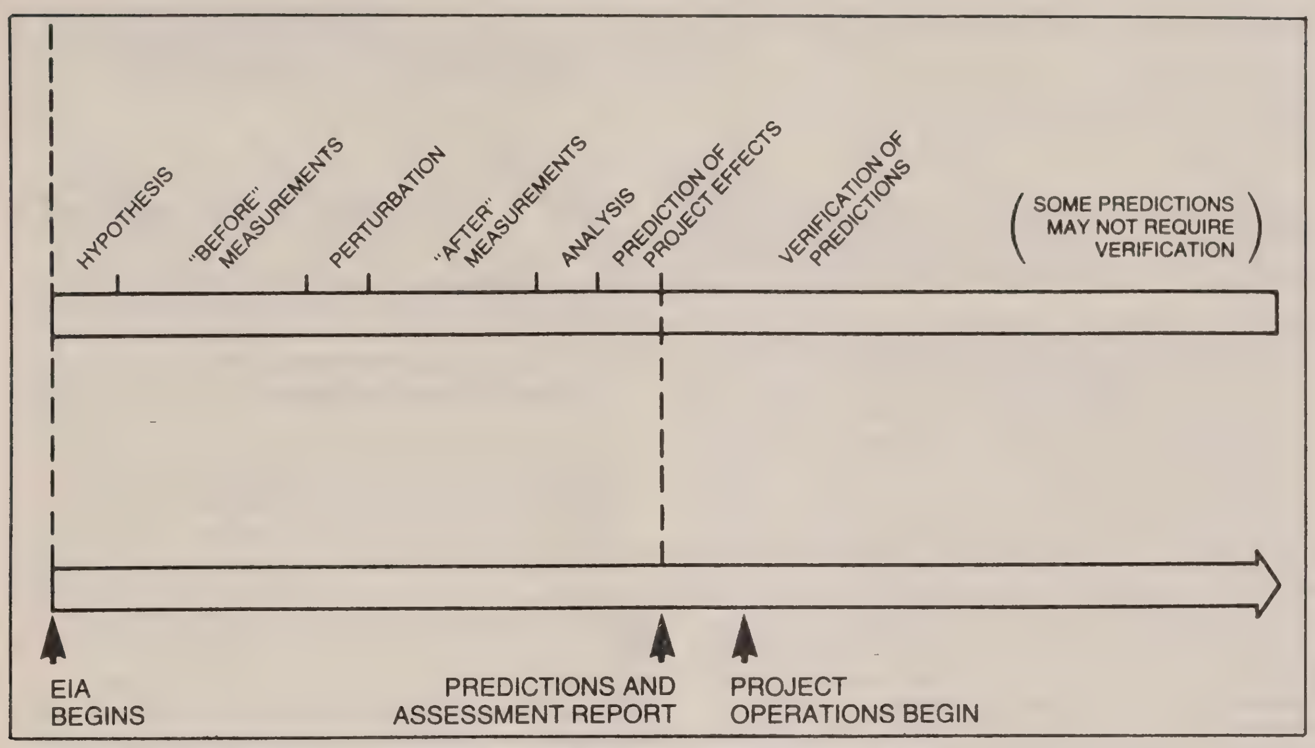


FIGURE 8-4 A PRE-PROJECT EXPERIMENT IN AN IMPACT ASSESSMENT CONTEXT

defined jargon of environmental impact assessment into an experimental context. As shown in Figure 8-5, this means that initial literature reviews and reconnaissance surveys should be directed towards the establishment of working hypotheses. In the words of Fritz and others (1980), "Perhaps the most important facet of system conceptualization is the formulation and formalization of hypotheses."

In such an experimental context, baseline studies would become statistically adequate measurements of selected environmental variables before project initiation — in effect, a statistical definition of the natural variability of phenomena of interest. This would be a major departure from the current dominance of undirected descriptive exercises conducted under the banner of baseline studies.

The prediction of future impacts would be cast in the form of revised hypotheses, the testability of which would be assured by reference to pre-project measurements. Unfortunately, this is where most of our current project 'experiments' have been terminated; the treatment is applied but the experimental study ends.

From a scientific point of view, the objective of monitoring is to test hypotheses. Both in the minds of the workshop participants and in the literature there is a strong relationship between monitoring and baseline studies. For example, Hirsch (1980) defined a baseline study as "a description of conditions existing at a point in time against which subsequent changes can be detected through monitoring." More specifically, a group of research scientists reviewing impact assessment requirements in the off-shore marine environment suggested that baseline studies be designed, "to provide insights into the normal variability of phenomena such that appropriate monitoring programs can be designed" (Anonymous, 1975). In order to test an hypothesis, the same statistical requirements would have to apply to 'after' measurements as to 'before' measurements.

The importance of attempting to establish an adequate baseline cannot be overestimated. Its absence places the interpretation of the results of an operational-phase monitoring programme in serious jeopardy. For example, Sage (1980) discussed the environmental impacts from a subterranean rupture of the Trans-Alaska Oil Pipeline in 1979. It was presumed that more than a thousand barrels of crude oil entered the Atigun River. Because of the absence of suitable baseline data, Sage concluded that "the actual effects of the oil on fish and other aquatic species of the Atigun River will probably never be determined."

It is only in this experimental context that the scientific implications of environmental impact assessment have their full meaning. According to many workshop participants and a number of authors, the knowledge that the accuracy of impact predictions will not likely be determined leads to an overall downgrading of the scientific foundation for all aspects of assessment studies. Vague predictions do not require data from statistically valid sampling programmes, nor are such predictions generally testable in a quantitative sense. Although the idea of project experimentation as oulined above often may not be applicable in its total concept, a general acceptance of the principle would result in a

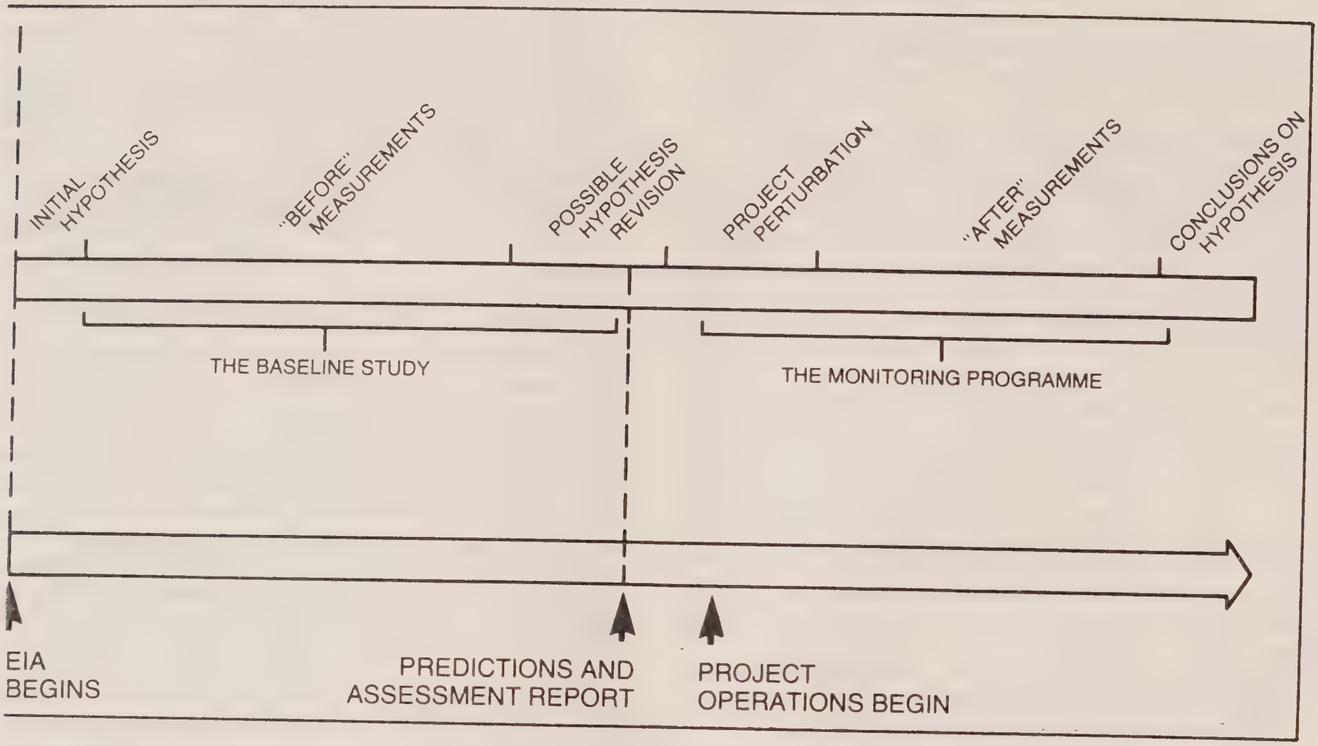


FIGURE 8-5 AN EXPERIMENTAL CONTEXT FOR STUDYING PROJECT EFFECTS

major improvements in the entire range of impact assessment studies.

An excellent example of studying a full-scale project experimentally consists of a long-term investigation into the effects of the Upper Salmon Hydroelectric Development in Newfoundland on local caribou herds (Mahoney, 1980; Newfoundland and Labrador Hydro, 1981a). Behaviour, migration and distribution studies were undertaken for a two-year period prior to construction, continued for a two-year period during the construction phase and will be continued for two years after the project begins operation.

Examination of Similar Projects

The concept of studying previously completed developments also has application potential in environmental impact assessment. There are some obvious drawbacks, mainly the lack of pre-project data. However, there may be situations where reference sites within the general area, but not influenced by the project, could give some indication of original baseline conditions. For example, during one of the workshops dealing with the disposal of radioactive wastes, it was suggested that measurements of existing levels of radioactivity within and outside the sphere of influence of existing projects could provide useful information on the levels to be expected from a proposed development. Likewise, studies of impoundment conditions above existing dams may provide useful information for estimating the timing and magnitude of impacts expected to occur after the completion of a new dam. In this respect, the long-term physical and biological consequences of dam construction in temperate latitudes are reasonably well known (Lowe-McConnell, 1973; Baxter, 1977; Baxter and Glaude, 1980) and, as of 1972, there were about 80 major hydroelectric projects in Canada that could be examined (Efford, 1975).

In closing this section, we stress the need to adopt a variety of experimental approaches to impact assessment studies. The essence of environmental impact assessment is to accurately predict project-related changes in selected environmental variables. This can best be achieved by combining the lessons to be learned from similar projects, by the use of laboratory or field experiments where appropriate and by studying the project itself in an experimental context.

"It is acceptable for an EIA to admit that prediction is not possible — in that case, the project should be treated as an experiment, with monitoring to test hypotheses. At least you'll be able to build the next project a little better."

"In the future, we will probably get more useful data from using projects as case histories and as experiments than we will from pre-project experimental programmes."

"In my view, EIA should take the form of pilot-scale developments."

"We should adopt the following principle for EIA — 'look at other projects of a similar nature'."

"Let's get back to using case studies!"

9 — DEVELOPING AN ECOLOGICAL PERSPECTIVE

LESSONS FROM EXPERIENCE

"The challenge we have in impact assessment is to find the best regrouping of scientific tools and disciplines to fit the EIS needs."

"We should study the pertinent where possible, not study whatever possible and then decide on the pertinence."

"I believe a well-informed group of scientists, given a week or two of time, could produce just as good an EIS as two years and millions of dollars spent on our current type of baseline studies. The EIS would then recommend a couple of well-directed studies in support of the overall assessment."

"An ecological focus in impact assessment is not necessarily *an ecosystem focus."*

"We should only focus on the community and ecosystem levels where necessary for special emphasis; however, our current knowledge at these levels does not lend itself to prediction."

"I think it would be unwise to dispense entirely with the concept of ecosystem in impact assessment, especially for unique systems like estuaries and wetlands."

An upgrading of the ecological basis for assessment studies is not a panacea for all that ails environmental impact assessment in Canada. Nevertheless, it can be argued that the notion of impact assessment is equivalent to applied ecology. Adherence to basic ecological concepts whenever possible could be a major factor in focussing the considerable efforts now expended in assessment studies. Thus, the ranking of ecological studies by priority to be undertaken should reflect, in part, the extent to which the science of ecology has developed a conceptual or theoretical knowledge base for the particular natural phenomena of interest. The ecological concepts considered most applicable should be used in organizing and designing the studies, provided the concepts are well enough understood and can be applied within realistic commitments of time and resources.

The result should be a more limited and focussed study effort based on a compromise between the information needs of the decision-makers, and what a sound, short-term applied science programme can provide. In the case of pre-development studies, the most immediate need is for greater efforts at developing the appropriate conceptual framework and ecological rationale to guide the design and conduct of the studies in a more efficient manner. In post-development monitoring programmes, the time factor is somewhat less of a constraint; however, similar ecological frameworks must be established at the outset since the utility of monitoring results depends on the design integrity of initial studies conducted prior to project initiation. Finally, the basis for impact prediction can be strengthened through an emphasis on understanding ecological functions and processes.

The remaining chapters in this part of the report provide a number of examples where ecological concepts have been suggested or used in impact assessment studies or closely allied activities. They reflect the intuition and imagination of the investigators involved and demonstrate the potential scope for developing ecological approaches to impact assessment studies. Although such examples of ecological approaches provide the most tangible direction to those involved in environmental impact assessment, there are a number of general lessons which can be drawn from experience. These generalizations reflect the scientific requirements reviewed in the previous sections as well as some ecological considerations with respect to setting objectives for environmental impact assessment and organizing the component studies. Those involved in conducting or reviewing impact assessments would do well to consider the implications of the following lessons to their particular studies before embarking on expensive and time-consuming data collection programmes.

(a) Always strive to develop a study design which assumes an opportunity to measure changes after project initiation.

The assumption that post-development monitoring will be undertaken (irrespective of whether it actually is) will force the investigators to be more judicious in choosing the environmental components to be studied. Careful consideration will have to be given to the possibility of obtaining reasonably accurate measurements within the time available, as well as the degree to which the components are expected to be affected by the project. If it is not assumed that monitoring will be conducted, it is unlikely that an appropriate basis for measuring change will be established at the outset.

(b) Strike a compromise between studying the valued ecosystem components and the nearest surrogate components for which useful predictions are possible; use professional judgement to extrapolate from the predictions to the valued ecosystem components.

For a variety of reasons, it is often not possible to predict with any useful degree of accuracy the effects of a project on the species of interest to the general public. In such cases, studies should be focussed on physical or biological variables which are closely linked to such high-profile species, and which are amenable to experimentation and modelling. It would then be necessary to extrapolate the

of such studies through expert opinion to the valued tem component. Such an approach would acknowl- our limited capabilities for predicting biological s at higher levels in the trophic structure and would te advice based on facts from conclusions based on ;ional judgement.

ˉake maximum advantage of the information which ;an be obtained from natural or man-made occur- ences and natural records.

ever possible, a retrospective analysis of the effects ious events, either natural occurrences or human s, relevant to the planned action should be con- Such studies could provide valuable insights into ironmental effects expected from projects involving ɔerturbations. Likewise, every effort should be made ıd baseline data backward in time through an anal- the evidence of past conditions as recorded in the of organisms or in the physical and biological lation of material.

ɔcus numerical data collection programmes around statistical definition of the natural variation of envi- ›nmental components in space and time.

ıeral, the reliance which can be placed on a sample ›ment is related to its resolution in a statistical Nithout adequate statistical definition of variables, no objective way to separate project-induced ; from natural variability.

›fine a hunch concerning a potential impact until it ın be stated as a specific question for which a ımerical answer is possible, or stated as a hypothe- ; which can be tested.

osing of vague questions is an indication of the focus for the study effort. If it is not possible to h some degree of clarity the problem at hand, then ıot likely ready to attempt a solution. An early to develop specific questions will not only ensure ›ntire study effort is thought through beforehand, it lso increase the utility level of the information gen-

t attempt to predict project-induced changes in sical and chemical components and their direct acts on organisms. Then focus attention on indi- : effects operating through changes in habitat or ɟ.

ıl transport and fate models are, in general, much ıble as predictive tools than models incorporating phenomena. Since the biological components of ns normally respond to changes in physical or components, it makes sense to attempt initially to d these latter changes. Environmental impact nts often focus on habitat as the main link ıbiotic and biotic components of the ecosystem. ıtation or modelling or both should be attempted te the loss of habitat into long-term implications ɔortant species.

(g) It may be as important to consider the long-term potential of the ecosystem (or components of it) to recover from an expected impact, as it is to predict the initial outcome of the perturbation.

All too often environmental impact assessments get caught up with impacts as such, rather than the ecological consequences of the impacts. Intuitively, we should be cautious about disturbing natural systems which are thought to have low levels of resilience. Some initial attempt to characterize ecosystems from this perspective could substantially influence the levels of effort directed towards impact predictions.

"Sediment analysis serves as a good historical record. EIA should always try to capitalize on natural archives."

"We need to have a clear fix on the physical aspects of the project before we can ask specific ecological questions."

"A study design, and thus the inferences that can be made, is shaky when a study begins in earnest only after an upset has occurred."

"Too often the questions asked in EIA are so general that they cannot be answered."

"The first checklist to make when beginning an impact assessment is one of all the persons who could conceivably have anything to contribute or say about it."

"An assessment for a polluting project should begin by looking at crude mass balances."

CONCEPTUALIZING THE PROJECT AND THE ENVIRONMENT

The Project

It is common for those conducting environmental impact assessments to be directed to, figuratively speaking, 'overlay the project on the environment.' This is normally used as the rationale for obtaining detailed information on the various aspects of the project as soon as possible. Eventually, such information would be required in order to design in detail the required assessment studies. However, as emphasized by a number of workshop participants and authors (Holling, 1978; Fritz *et al.*, 1980; Kumar, 1980; Truett, 1980), there is a need to attempt to conceptualize the project-environment interactions at an early stage in study design. Such a conceptualization effort should help to establish the most appropriate overall study framework within the contexts of ecology and the impact assessment process.

Concepts are simply aids to understanding. There may be several correct concepts for any particular phenomenon, although some may be closer approximations of reality than others. The above-noted authors have provided a number of examples where conceptual approaches were developed for various projects and resource management problems; the reader is encouraged to refer to their publications for detailed descriptions. In most cases, they have

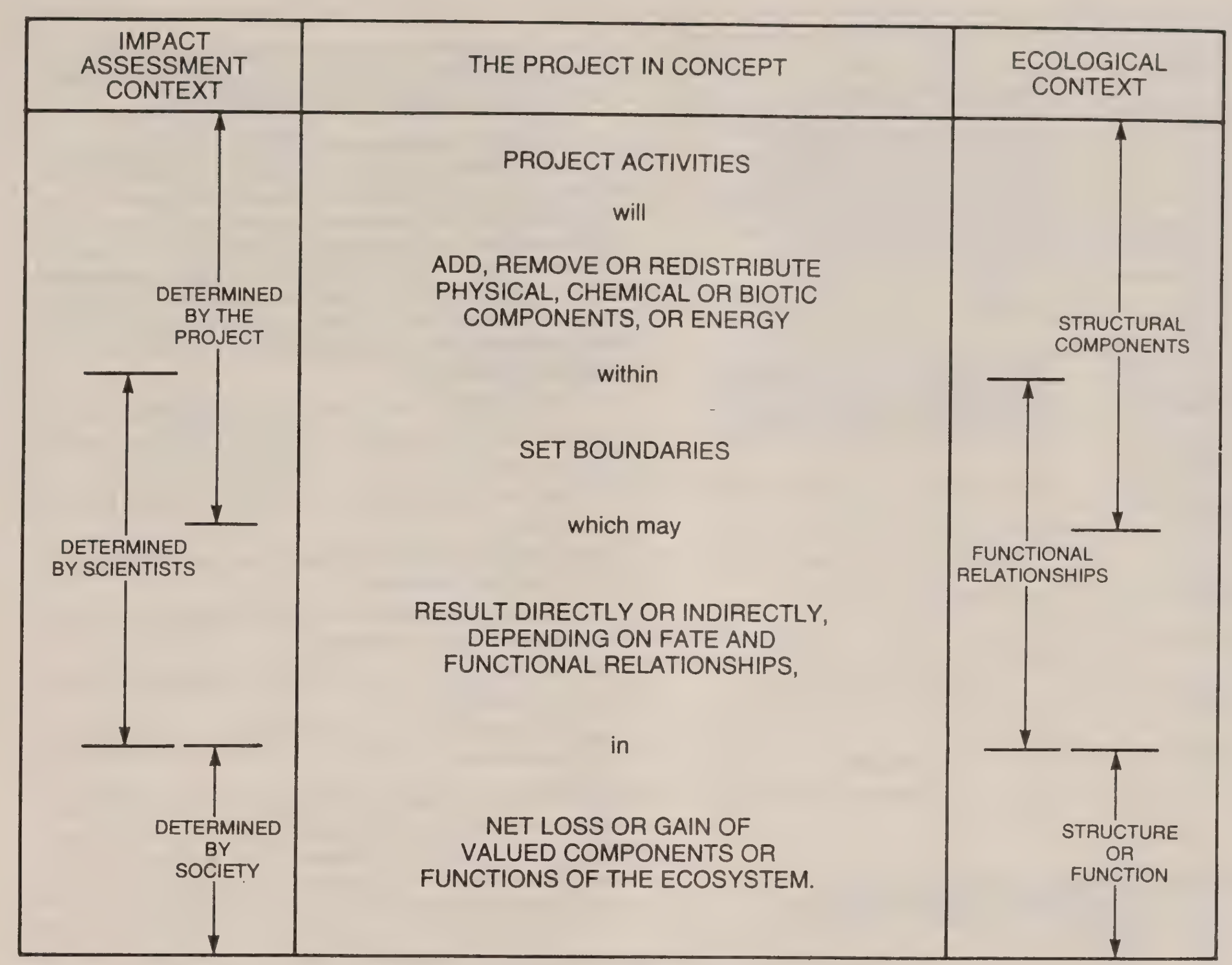


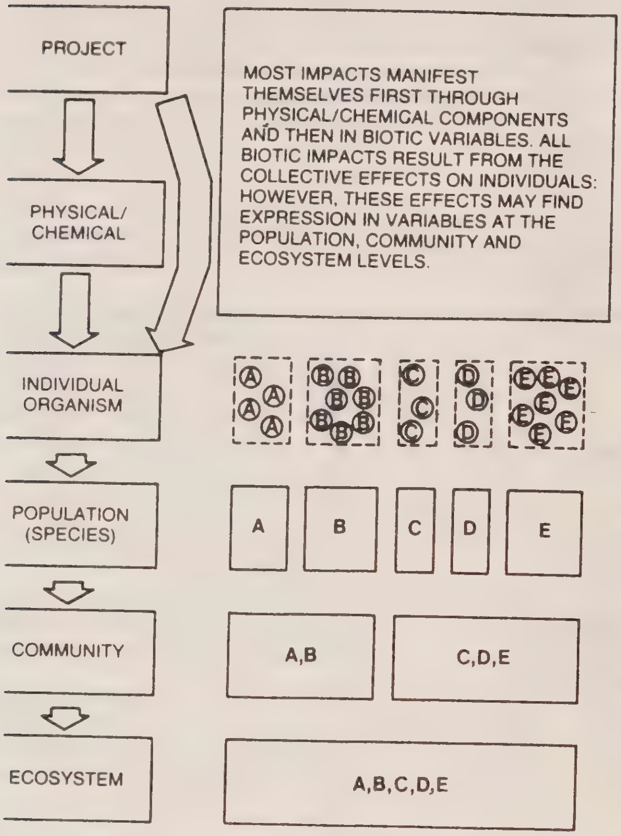
FIGURE 9-1 PROJECT EFFECTS IN ECOLOGICAL AND ASSESSMENT CONTEXTS

suggested that the benefits to the investigators derived as much from the process of conceptualization as from the concepts themselves.

This section outlines a broader conceptual framework which we believe is helpful in placing a project in an ecological and impact assessment context (Figure 9-1). It starts with the basic premise that, from a systems point of view, individual construction or operation activities of a project will result in physical (e.g., sediment, water, minerals), chemical (e.g., oil, pesticides, industrial wastes) or biotic (e.g., crops, predators, diseases) components, or energy (e.g., heat), being introduced into, withdrawn from, or redistributed within a natural system as delineated by set boundaries. It is assumed that the nature and level of the components, or the amount of energy, can be determined from project details. At this stage, the framework reflects the concepts underlying input-output models.

Initially, such additions, deletions or redistributions can be considered to constitute structural changes to the system. In environmental impact assessment, the role of the applied scientist is to determine whether these changes result in losses of valued components of the system. The characteristics of such components, along with the nature of the additions, deletions or redistributions involved, will determine the range of choices available for studying potential direct impacts (the appropriate transport and fate models) and higher order effects (the relevant ecological relationships and functions). These choices, in turn, should lead to a more detailed modelling exercise or a range of laboratory or field experiments or both.

The advantages of even such a basic conceptual framework are obvious. For example, a project activity could involve the addition of a heavy metal to an aquatic system, in known operational or upset amounts. The characteristics



GURE 9-2 CHAIN OF IMPACT AND THE STRUCTURAL RELATIONSHIPS OF BIOTA

the metal would determine the extent to which it could transported by water or accumulated and transported in diments or by both means; if they were not known, ›oratory or field experiments could provide some guid- ce. The obvious ecological phenomenon of interest uld be bioaccumulation, the application of which would olve dose-response experiments using the identified tar- t species, or food chain studies if trophic linkages were olved. Such focussed activities would also identify the ed for specific, quantitative baseline data.

\s another example, a project activity such as a drainage gramme might be expected to result in the withdrawal of ter from an extensive area of wetlands. Hydrologic mod- could provide the basis for predicting the level at which lowered water table would be stabilized. The general ıciples of plant community succession, applied to the cies complex in the wetlands and the expected changes he moisture regime, could be used to predict the future ıt community within specified time and space bound- s. Predicting, in any rigorous sense, the effects of the ılting habitat changes on species of concern would be cult due to the complexity of most species-habitat inter- actions. Furthermore, it would be unlikely that the effects of the loss of habitat on the longer-term population dynamics of such species could be determined beforehand.

As implied by these examples, the logic sequence resulting from a conceptual framework can be quite simple. On the other hand, the framework presented in Figure 9-1 can be amplified as the functional relationships between the project activities and components of value are developed in more detail; in effect, it becomes a working conceptual model. Regardless of the detail to which this conceptual framework, or any other, is developed by those conducting impact assessments, the resulting studies would have the following advantages:

(a) a separation of the project into manageable parts;

(b) a focus on the nature and the source of the perturbation;

(c) the early establishment of time and space boundaries;

(d) a recognition of the valued ecosystem components within the assessment;

(e) a logical progression from physical-chemical components to biotic components;

(f) the consideration of functional relationships wherever possible; and

(g) a recognizable format within which to present the study results.

Unfortunately, for whatever reasons, it is rare to find an environmental impact assessment organized around any recognizable conceptual framework. This often results in an initial infatuation with the 'pipes and fittings' of the project and the consequent lack of an ecological perspective.

The Environment

It is equally important to conceptualize the environment in an ecological sense, keeping the project firmly in mind. In the tradition of 'overlaying the project on the environment,' the 'environment' usually has consisted of an extensive verbal description, with limited quantitative support, of various structural elements of the system. This gives little direction on how the project may interact with those structural elements, especially the biota. We suggest that an earlier, more conceptual view of the environment would begin to guide the practitioner in identifying important project-environment interactions and in rationalizing the study approaches required to elucidate those interactions.

We present here two generalized conceptual frameworks for the biotic realm of the environment. These frameworks at first may appear rather academic, without much application potential in the real world of impact assessment. However, there is little hope of having advanced conceptual or mathematical models adopted as analytical frameworks until there is some evidence that even basic ecological concepts are being used to advantage. The following discussion will show how simple ecological beginnings can provide some guidance in the approach to, and ultimate design

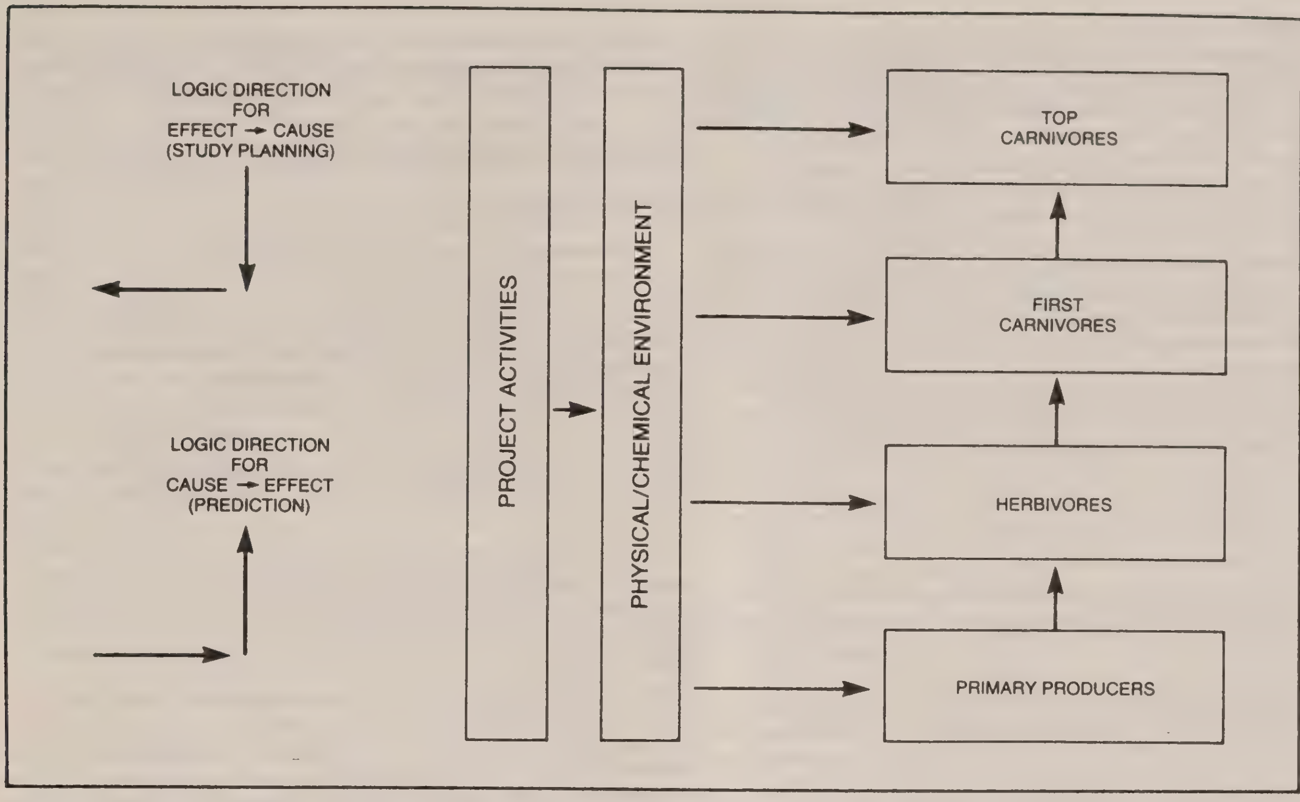


FIGURE 9-3 CHAIN OF IMPACT AND THE FUNCTIONAL RELATIONSHIPS OF BIOTA

of, impact assessment studies. The frameworks described below are not the only approaches to conceptualizing the environment that can be of assistance; several authors (e.g., Fritz *et al.*, 1980; Kumar, 1980) have suggested perspectives on the environment from the point of view of assessment procedures. As well, it was clear at the workshops that many consultants and proponents directly involved with assessments have personal approaches on how to conceptualize the environment. Nevertheless, we present the following frameworks in support of our message that such groundwork must precede study planning so that the field programme and predictive analysis have well-defined directions.

In ecology, we recognize that a population is a special assemblage of organisms of a species, that a community is an assemblage of species populations, and that the total biotic realm within an ecosystem represents either a community or an assemblage of communities, depending on how the ecosystem is defined and bounded. The first framework (Figure 9-2) is derived from a recognition that responses of biota, at any level of the ecological hierarchy, to perturbations are realized through some combination of responses at the level of individual organisms. From an impact assessment perspective, this mode of thinking is fundamental to two basic questions asked by the scientist: (i) at what biological level are the valued ecosystem components in this assessment, and (ii) at what biological level is it possible either to predict or detect the expected perturbation? Unfortunately for everyone involved, the levels often do not coincide. The majority of concerns seem to lie at the population level — how will population X be affected by the project? Occasionally, the concerns are at the level of community or ecosystem; for example, a relict forest community, or a salt marsh ecosystem.

On the other hand, our ability to predict or measure changes due to human activities if often very weak at the level of the population. This may be attributed partly to our lack of understanding of the mechanisms that control population variables, and partly to the extreme natural variability inherent in such variables. Our best chances for accurate prediction and for success in detecting change may lie at the level of the individual organism (and perhaps to a limited extent at the community and ecosystem levels). What the reference framework in Figure 9-2 implies is that in cases where it appears impractical either to predict or measure changes at the population level for a species of concern, it may be expedient first to examine the response of individuals to a project-induced change and then attempt to extrapolate these individual responses into a response at the population level. By conceptualizing the biota in this way one may be guided toward the most promising avenue for study.

Our second framework involves a special look at the ›phic structure of the environment in question (Figure 9- . The linkages between the various levels become very portant when dealing with impacts that reach the species concern through the food chain. The first message from › diagram is that the project, usually acting through the ysical and chemical environment, may have its first effect biota at any (or all) of the levels of the food web. If the el affected coincides with the level of the species of con-·n, then a food-chain linkage is not implicated. This uld be the case, for example, if flightless murres (a sub-:tic colonial seabird) were to encounter an oil slick during ir late summer marine migration. Such direct interactions often not the case, since (i) species of concern are ariably located high in the trophic structure of their com-nities, and (ii) projects often interfere with species and logical functions occurring at the base of the trophic cture.

he workshops generated a substantial amount of dis-sion on perspectives of the food chain, especially in tion to the direction of examining it — from the top 'n, or from the bottom up. It appears to us that in plan- a study program for an impact assessment, it is edient first to identify the trophic level of the species of cern (that is, species on which assessment studies will ocussed) as well as the level at which the project is ected to initially affect the biota, and then to identify ›rtant processes and feeding relationships (i.e., cause, :t and controlling mechanisms) *down* through the sys- (see Truett (1978) for a further rationale). On the other l, in attempting to predict impacts, one would normally the impact from the project, through the ical/chemical environment, through the lower levels of rophic structure (if appropriate) and then to the spe- of concern. These are opposite directions through the set of linkages but both appear to have an important in the consideration of a basic approach to environ-al assessment studies.

have presented these frameworks not because we romoting them as *the* basis for conceptualizing envi-ental impacts; rather, we feel that an early and serious deration of the fundamental constraints and oppor-s for assessment studies evident through examining simple diagrams should force practitioners to com-ate the ecological realities of their proposed study ımmes.

"n individual is not affected by a suspected source npact, then the population will certainly not be cted."

› sequence I use in conceptualizing impacts starts physical changes, and progresses to the bottom of ood chain and then up. But I still have to know 's important at the top so I can decide what to at the bottom."

personal approach is to start with the end-points, include the important attributes to be evaluated, hen trace these back to the project."

"The trophic structure is a convenient and revealing way to link biota, and since most of what EIA does concerns impacts on biota, it can be very important."

SOCIAL VERSUS ECOLOGICAL SCOPING

Social Scoping

"We definitely need a set of formal sieves to focus on the ultimate ecological concerns."

"You have to give priority what you want to study because you can't study everything. One basis for ranking by priority is to focus on economically and ecologically important species."

"In thinking about a baseline data collection programme, industry first finds out what the public and the bureaucrats are interested in, which usually are population levels."

The term scoping has recently appeared on the environmental impact assessment scene as a result of the 1979 Regulations under NEPA, which require lead agencies to undertake "an early and open process for determining the scope of issues to be addressed and for identifying the significant issues related to a proposed action" (Council on Environmental Quality, 1980). The agencies are to achieve this objective through careful consideration of existing information relevant to the assessment as well as organized involvement of other agencies and consultations with the general public.

This is a somewhat belated recognition of the need to establish clearly the focal points for an assessment at the outset; failure to do so severely limits the probability of obtaining useful and credible results. Scoping, in effect, provides a means whereby the public has a role in translating the policy wording of NEPA, that is, "restoring and maintaining environmental quality to the overall welfare and development of man", into tangible direction for specific impact assessments. A consideration of Figure 9-1 without the bottom element gives an indication of the problems posed for assessment studies when some form of social scoping is not undertaken.

There is no sure way to second-guess the general public on this matter, if for no other reason than that social values change with time. As discussed earlier, the workshop participants collectively provided their opinions on environmental factors which probably influence society's interpretation of importance. Although such social scoping can verge on the philosophical, it can result in concepts that become formal requirements for impact assessment. For example, consider the following quote from the U. S. Atomic Energy Commission's Directorate of Regulatory Standards (USAEC, 1973; as quoted by Eberhardt, 1976).

"A species, whether animal or plant, is 'important' (1) if it is commercially or recreationally valuable, (2) if it is rare or endangered, or (3) if it affects the well-being of some important species within criteria (1) or (2) above, or (4) if it is critical to the structure and function of the ecological system."

As Eberhardt (1976) noted, it is virtually impossible to translate phrases like 'well-being' into an operational focus for a study; nor would we, in most cases, understand the structure and function of natural systems, let alone be able to determine the critical nature of various components.

To be useful as an operational guide, social scoping is often cast in terms of the plant or animal species perceived by society to be important. Thus, among other more ecological criteria, Cairns (1975) used commercial, recreational or aesthetic values as some of the bases for establishing a list of critical species. Similarly, Truett (1978) established the focus for a major impact research programme on 'key species' which were defined on the basis of abundance, and commercial, recreational and food value to man. In the words of Truett (1978):

> "There was good reason for concentrating research on species considered to be of immediate value to society. The reason relates both to the difficulty of assigning an environmental value to species not useful to man and to the fact that species with little value are of little concern to decision-makers. And, lest we forget, the ultimate purpose of an assessment study is to influence decision."

Two publications which provide the most detailed technical direction to those undertaking impact assessments (Fritz *et al.*, 1980; and States *et al.*, 1978), have both treated social and economic values as major factors in concentrating the range of ecosystem components into a more limited study.

In some respects, adopting a definition for significant impact represents an initial attempt to reduce the scope of assessment studies to the most important potential effects. This was reflected in the assessment report for the South Davis Strait off-shore exploration programme (Imperial Oil Ltd. *et al.*, 1978) where significance was taken to include reductions in populations of species of subsistence or commercial importance to local users. Likewise, a company representative participating in one of the workshops indicated the regular use of a simple scoping exercise to focus the assessment study effort. This included four categories of species — commercially important, important as indicators, ecologically important and those species high in the trophic structure. Some attempt is made to include a few species from each category in impact assessment studies.

During the workshops, there was general agreement on the need for social scoping very early in the assessment process. Recent hearings to discuss the draft assessment guidelines for the Beaufort Sea Hydrocarbon Production Proposal can be considered as a scoping exercise. It is not apparent, however, from the final guidelines (Beaufort Sea Environmental Assessment Panel, 1982) that the exercise was entirely successful. The document directs the proponents to discuss the biological environment ranging from micro-organisms to mammals. While later sections suggest that studies should be limited to effects "that are deemed to be significant," it is only at the end of an appendix to the guidelines that the true meaning of this becomes apparent, that is, "species that at present are of direct value to society such as those that may be considered rare or endangered or important for subsistence, scientific, commercial or recreational use."

Ecological Scoping

While social scoping of an assessment depends upon public opinion and value judgements, the translation of concern for valued ecosystem components into appropriate ecologically-framed studies is the purview of the scientists. Since predicting directly the impacts of a project on a species of concern is often very difficult, the challenge becomes approximating such impacts indirectly. In this context, social scoping can be considered as the establishment of the terms in which impacts should be *expressed* while ecological scoping establishes the terms under which the impacts can effectively be *studied*, or need to be studied.

Determining the ecological scope of an impact assessment can be approached by addressing the following four basic questions:

(a) Is there reason to believe that the valued ecosystem components will be affected either directly or indirectly by the project?

This would appear to be the first obvious question to ask, yet it is often overlooked in impact assessment studies. Perhaps this is the logical outcome of not establishing the valued ecosystem components at the outset. In most cases, the answer to this question will not be evident without some basic understanding of the project, some preliminary review of the literature and the results of reconnaissance surveys.

Fritz and others (1980) noted that a basic knowledge of the perturbations resulting from a project, when compared with the physiological, life history or population characteristics of the species of concern, should give a preliminary indication of probability for interaction. The assessments for two hydroelectric projects in Newfoundland are cases in point. It is generally accepted that woodland caribou in that province is such a species of concern. It was noted in early studies on the Upper Salmon development (Newfoundland and Labrador Hydro, 1980a; 1981a) that the area to be affected by the project included critical caribou calving habitat and migration routes. The result was the initiation of long-term caribou studies. In contrast, surveys in the general vicinity of the Cat Arm project (Newfoundland and Labrador Hydro, 1980b; 1981b) showed that there would be minimal interaction with caribou and no further studies were undertaken.

The reverse situation can also develop. For example, interviews with persons involved in the South Davis Strait project revealed that walrus were originally excluded from the assessment. However, they were added later when field surveys revealed that a number of colonies existed within the sphere of influence of the project.

This initial question concerning the possibility for inter-ıction between project and the valued ecosystem compo-ıents applies to ecological processes as well as species. ·or example, Truett (1978), in reviewing the selection of ey processes for study (processes considered to be criti-al to the key species) initially included the regulatory effect f incident light on phytoplankton production in a marine ıgoon. However, since the project under consideration was ot expected to influence the light regimes, the effects of ȷht on phytoplankton were not studied.

"Ideally, you study only those ecosystem components and processes that are implicated in project impacts."

ı) Is it realistic to attempt to study the effects on the valued ecosystem components directly?

When the valued ecosystem components are species ·pulations, which they often are, it is difficult to predict or ·easure project impacts in terms of changes in these pulations. As discussed earlier, the difficulties can be ced to variability in space and time which poses serious mpling problems. In a comprehensive discussion of varia-ty in population studies, Eberhardt (1978) summarizes · problem as, "How small a change or difference will a en study reliably detect?". It is clear from his review and er studies (Anonymous, 1974; Hartzbank and Cusker, 1979) that the sampling intensity required to ect even major changes in population sizes may be quite ·ond the capability of environmental impact assessment.

·his realization is particularly evident in marine ecosys-ıs where most populations are extremely variable over · and are mobile. The results of a workshop examining consequences of hydrocarbon development on the ıadian offshore clearly demonstrated the magnitude of problem (Anonymous, 1981a). Thus, owing to the con-ints of sampling density, confidence limits, behaviour natural variability, adult mortality of less than 25 per : in most off-shore fisheries would not be detectable g present baseline data and monitoring programmes. nermore, Cox and others (1980) noted that even if ıges can be determined statistically, the problem of ·ality remains. They went on to conclude that:

·ince obvious and measurable mortalities of large ·bile species are an extremely rare occurrence, it is ggested that quantitative evaluation of the impact of on a particular species, measured by adult mortality anges, is impossible."

impact assessment studies, it may be possible to sam-ome highly mobile species if they congregate at certain ·. For example, workshop participants stressed the ntages of counting seabirds in their colonies instead of ·uring abundance based on distributional patterns. · examples would include the aggregation of ungulates ılving or overwintering habitat and the return of ana-ous fish species to pre-determined spawning areas. ugh the sampling advantages from such behavioural cteristics are significant, there was little evidence in ·eview of Canadian impact assessments that these ıtages were taken into account in the design of sment studies.

(c) How can the effects on valued ecosystem components be studied indirectly?

If it is unrealistic to attempt to predict or measure changes directly in the valued ecosystem components, then there appear to be four basic choices which are discussed below. All of these choices imply that the impacts are occurring indirectly through ecological relationships.

(i) Move up or down in the food chain.

For some practitioners of impact assessment, ecological scoping means moving up or down in the food chain to a level which is closely linked with the high-profile species but which is more amenable to laboratory or field investigations. For example, Fritz and others (1980), in addition to including species valued by man as the focal point for assessment studies, also included: (i) species which are instrumental in the formation of habitat, (ii) species which provide forage for the valued species, (iii) major predators in the system, and (iv) those that are vulnerable to the projected source of impact. Similarly, Truett (1980) included among his key species, three species of micro-organisms since they collectively represented the major food source for the high trophic level species of concern.

The food chain approach can also involve bioaccumulation studies. This approach was advocated at one of the workshops when the participants were considering the design of studies to assess the impacts of the disposal of radioactive mine wastes. In this case, one of the species of concern was caribou and the objective was to predict the body load of specific radionuclides in those animals affected by the project. However, because of the unpredictable movements of caribou through the area and a lack of information on feeding behaviour, it was decided that this objective could not be attained directly. Instead, the study was to focus on predicting the equilibrium body loads of radionuclides in lichens, the major food for caribou. This was considered to be a more realistic approach since lichens were widespread and easy to sample and relevant measurements could be obtained from other similar projects. The extrapolation to body loads in caribou would have had to be made on the basis of professional judgement.

(ii) Study earlier stages in the life history of the species of concern.

The rationale for this option is that the early life history stages of most species are more vulnerable to changes in their physical and chemical environments. While this may be true, there is no guarantee that sampling of immature stages will be less of a problem. For example, although the immature stages of most commercial species of marine fish are more susceptible to the toxic effects of oil than adults, current monitoring programmes probably are not able to detect less than order of magnitude departures from normal population levels (Anonymous, 1981a). Added to this is the difficulty in projecting such changes into impacts on the adult stocks supporting the fishery owing to the high variability of natural recruitment.

"Prepubertal life stages are much more sensitive to perturbation than any adult stage."

"The individual level to me means physiological and pathological studies, preferably in the field. Focussing here can serve as a 'red flag' for effects in higher levels."

"Individuals are likely to display effects before they appear in population characteristics; hence you can buy time by focussing on individuals."

(iii) Study sublethal effects at the level of the individual.

There is an emerging consensus, at least among marine fisheries biologists, that our capability for predicting and measuring impacts may be much better at the individual rather than the population level (Anonymous, 1974; Anonymous, 1975a; Anonymous, 1981a). Impact assessment studies on individual organisms have the following advantages: (i) the sampling programme for individual-level characteristics is often much more tractable than attempting to obtain an adequate sample for estimating population characteristics; (ii) impacts often are evident in individuals before they are evident in population characteristics, and thus some advance warning of population impacts may be given; and (iii) study design can be improved because of the relative ease of measuring control individuals outside of the sphere of the project. As summarized by Brungs (1980), "Sublethal and chronic toxicity data from field and laboratory studies are available for direct and indirect effects of a wide variety of toxic materials or conditions and should be extensively used in the preparation and review of environmental impact statements or related documents."

(iv) Study impacts on the habitat of the species of concern.

Organisms are often affected by development projects through changes in their habitat. Indeed, the review of selected Canadian impact assessments showed that habitat is the most common focus for literature surveys and field studies. Unfortunately, habitat studies in impact assessments seldom get beyond the stage of documenting the existence of some biophysical conditions known to be suitable for certain species — much as a wandering field naturalist would make notes in a journal. In most cases, such habitat references are not suitable for determining the impacts on populations of concern owing to a total lack of quantification and no knowledge of relevant species-habitat interactions. There are, however, other more pragmatic problems related to the use of habitat. For example, the results of habitat studies conducted in support of an assessment for a mining project (Saskatchewan Research Council, 1981) were complicated as a result of a forest fire which swept through the area just prior to the initiation of the project.

Some impact assessments have included quite a thorough descriptive and interpretive approach to habitat, mainly through a classification of vegetation communities (e.g., Gulf Canada Resources Inc., 1980). Other investigators have shown that a reasonably quantitative approach can be adopted (e.g., Beak Consultants Limited, 1980). In the latter case, spawning and rearing habitats for salmonid species were first classified according to a variety of physical and biological characteristics known to be important, and subsequently inventoried. It was then possible to predict the number of units of habitat which would be lost following construction of the hydroelectric project. For example, it was stated that "about 340 units or 20 per cent of available good rearing habitat will be lost in the tributaries due to flooding." Although not dealing directly with the populations of concern, this approach to habitat studies is a substantial improvement over the descriptive epitomes so common in assessment reports.

"Habitat is often easier to predict largely because project effects on habitat are first order."

"I find it necessary to link the population level with habitat. I look at the strength of the link, and at what is important in the habitat."

"We currently cannot predict caribou population changes from expected habitat changes."

(d) Is it necessary or helpful to use indicators of impact?

When all else fails, biologists involved in impact assessment studies may resort to the use of indicators as a means of obtaining some measurement of stress on a natural system. This would normally be a fall back position in the ecological scoping process when the possibilities for studying the valued ecosystem components, either directly or indirectly, are limited. Thus, we consider indicators as having no obvious relationships to the valued ecosystem components identified for an impact assessment.

The term *indicator* implies a movement of some variable away from a known or set normality, that is, it indicates that a change has occurred (Inhaber, 1977). As such, indicators have received a lot of attention in the context of baseline studies and monitoring but, by definition, have limited use in a predictive sense (Cooper, 1976b). Most of the following discussion will reflect this monitoring role for environmental indicators in impact assessment.

The majority of the publications on indicators of impact are related to their use for monitoring water quality. Averett (1981) gave a summary of the evolution in complexity and refinement of indicators for that purpose. The use of indicators in a marine context has been reviewed by IMCO and others (1980), and Swartz (1980). A report in the United States by the Committee on the Atmosphere and the Biosphere (1981) included a summary of indicators for monitoring atmospheric pollution. In keeping with the general thrust of this report, we will limit our discussion to a few examples where indicators have been used in impact assessments or relevant studies.

Indicators of environmental stress have been developed for individual organisms, populations, communities and ecosystems. Baker (1976) provided an excellent summary of the range of species characteristics which should be considered in choosing indicator species (Table 9-1). Cooper (1976b) emphasized that the choice of an indicator species depends on its sensitivity to the expected perturbation (stress) and the degree to which its response is observ-

in space (the indicator stays in the stressed environ-) and time (the indicator responds to the stress without e time lags).

e pre-operational monitoring programme for the Point eau Nuclear Generating Station in southern New wick provides an excellent example of the use of spe- and population indicators (Smith *et al.*, 1981). This amme resulted from recommendations arising from nvironmental impact assessment for the power station. ving the establishment of boundaries for atmospheric narine dispersal of radionuclides (see Chapter 10 for s), indicator organisms were chosen on the basis of llowing criteria: (i) abundance and size, (ii) uniform ution, (iii) exposure to environmental reservoirs of ctivity, and (iv) position in the trophic structure. ples of organisms chosen include alder and mosses in rrestrial systems and leeches and frogs in the aquatic nment.

cern over the ecological effects of cooling water dis- es into the Bay of Fundy prompted the study of tors at the population and community levels. In the of Smith and others (1981), "Changes in such bio- functions as growth, respiration rate, reproduction ehaviour are possible, and could manifest themselves ered species diversity and community structure in tions of organisms exposed to the heated effluent." dingly, a sampling programme was initiated to deter- changes in benthic populations and communities hey were considered to be "ideal as indicators of ical effect." The entire monitoring programme for the Lepreau project is to be continued during operation of the power plant which commenced in 1982.

Table 9-1

A Classification of Indicator Species (from Baker, 1976)

	Characteristics	*Examples*
NEL	introduced; sensitive	limpet winkle Spartina
TOR	indigenous; sensitive	limpet lichen crustaceans
ITER	competitive advantage when subsidized	Enteromorpha
MULATOR	bioaccumulates chemicals	shellfish mosses lichens
SAY ANISMS	sensitive; suitable for lab tests	shrimp fish

As pointed out by Averett (1981), the general dissatisfaction with single species indicators in the monitoring of water quality led to the development of diversity indices at the community level in the ecological hierarchy. Mason (1978) described the procedures required to calculate an index value for use in determining the impacts of surface mining operations on water quality. It involves a comparison of the observed diversity of a benthic invertebrate community with an expected diversity based on control sites. Similarly, Wiederholm (1980) promoted the use of four different measures of benthic community structure for monitoring water quality. In a marine setting, Sharp and others (1979) argued that since cause and effect is extremely difficult to determine in natural systems, there is advantage in establishing monitoring programmes based on effects rather than suspected causes. They demonstrated the utility of using benthic community indices within a statistically valid sampling programme to monitor the effects of petroleum operations in estuarine and offshore areas.

Perhaps one of the best known industry-sponsored environmental monitoring programmes is that of British Petroleum (Cowell, 1978; Cowell and Monk, 1979; Cowell and Syratt, 1979). It involves the use of population and community indices for the intertidal zone of rocky shores. Through a process of characterizing intertidal benthic communities on the basis of the degree of wave exposure, it is possible to predict the community profile which would normally be expected to occur with a given exposure. This provides some basis for determining the possible impacts of contamination even though the shoreline may not have been previously surveyed. It has also been suggested that careful attention to the differences in size and vertical distribution of some widespread intertidal species (e.g., limpets) might provide evidence of impacts from contamination operating through interference with population recruitment.

There are a number of indices which have been developed or proposed for monitoring at the ecosystem level, although we know of no instance where they have been applied in assessment studies. O'Neill and others (1977) showed that soil nutrient loss was a better indicator of system stress than any of a number of biotic indicators. Also, Flora and Rosendahl (1982) demonstrated that specific conductance could be used as an early indicator of potentially broad changes in water quality. Finally, Odum and Cooley (1980) gave examples of ecosystem profiles and performance curves. In the former case, graphical relationships demonstrating levels or profiles of ecosystem or community properties, before and after a project is initiated, are compared to determine a measure of the impact on the system. Performance curves attempt a similar holistic indication of impacts by plotting impact against output responses at the ecosystem level. Although Odum and Cooley argued strongly in favour of adopting such approaches, there is no indication that they have been effectively used in in assessment studies.

"Usually the parameters most amenable to getting sound statistical fixes are not at all consequential to project decisions."

"An 'indicator species' itself is not necessarily important, but it can provide information better than other species."

"For an indicator you might choose a species that likes the effluent and when the species proliferates, that's the warning."

"You should include parameters to study in an impact assessment that serve as canaries regardless of their social or biological importance."

"We should seek indices of impact rather than attempt to quantify every individual impact."

Summary

This section has attempted to draw a distinction between identifying the valued ecosystem components for an impact assessment, as defined by the values and perceptions of society (social scoping), and the extent to which such components can be effectively studied directly or indirectly (ecological scoping). While there is some evidence of a growing awareness to undertake the former, it is unusual to see any effort to rationalize the study objectives based on ecological grounds as suggested by the latter. The end results of undertaking the two activities may lead to a more realistic set of expectations for all parties involved in conducting and reviewing the resulting studies.

A helpful way of making the distinction is to consider the explicit difference noted by Overton (1978) between impact and change. He suggested that the term *impact* attaches a value to a change, positive or negative, and thus relates to social scoping. Change itself, however, has no connotation of value and ecological scoping is an effort to determine which changes can be predicted or measured with a useful degree of accuracy and reliability.

DEVELOPING A STUDY STRATEGY

"You have to have a string to hang the study beads on."

General Considerations

The need to think an impact assessment through first cannot be overemphasized. More than any other single factor under the control of the practitioner, it is this lack of an initial framework for assessment studies that limits the effective deployment of time and resources. This deficiency also sets up a confrontational interaction with those who review the assessment since they focus their attention on criticising the details of the 'brickwork' rather than considering the underlying structural integrity of the assessment studies. It seems there is little to be gained from arguing over details if the basic approach, even if executed with perfection, is inappropriate to the task. In this context, assessment studies may adhere to all of the scientific rules and principles outlined above and still not be relevant to meeting the objectives for the assessment.

It can be argued that the pressures of time, particularly the problem of limited field seasons, often make it mandatory to initiate data gathering exercises as quickly as possible, with little time to consider the development of an underlying ecological motif. However, after reviewing the literature, listening to 150 workshop participants, analyzing a cross-section of impact assessments and conducting extensive interviews with some practitioners, we are not convinced that the constraints are primarily logistical in nature.

It is more likely a case of misunderstanding coupled with a lack of motivation and ability. Practitoners are often led by the literature to believe that the only answer to the poor state of affairs is a quantum leap ahead in the design and execution of assessment studies. We wish to emphasize, through the use of examples, that an ecological rationale for an impact assessment can be developed without launching immediately into the cutting edge of science. Even the most basic consideration of ecological frameworks most appropriate to the assessment in question can help to clarify the options for study and to avoid useless data collection programmes. Our objective in the following discussion is to convince those involved in assessment studies to attempt at least a basic ecological organization of their efforts and thus determine what can realistically be achieved. The general adoption of such a small step and the benefit which would be derived from it, may indeed be a quantum leap ahead.

Setting the Stage

"We should build a Cadillac framework but be prepared to modify it to Volkswagen size for many applications."

In discussing the role of ecology in environmental management, Bella and Overton (1972) compared the military definitions for strategy and tactics. The former is concerned with the comprehensive deployment of resources while the latter refers to the immediate or local deployment of resources. They noted that two important principles are involved: (i) tactical plans and actions are subordinate to strategic plans and (ii) strategic plans are limited by tactical capabilities. In their words, "Failure to observe these two principles could lead to military disaster."

Environmental impact assessment as generally conducted in Canada has been long on tactics and short on strategy, resulting in many worthless assessments. Field surveys and inventories, which are tactical in nature, seldom have been supported by an overall strategy for the assessment studies. This was reflected in the willingness of most workshop participants to discuss the operational (tactical) aspects of field programmes but a reluctance to deal with the strategies required to develop a predictive capability.

The previous sections of Chapter 9 have illustrated the rious elements leading to the development of a strategic ısis for conducting environmental impact assessment ɹdies. The following is a brief summary:

(a) A generalized conceptualization of a project in its ecological and assessment context (Figure 9-1) can help to clarify the relationship between, and focus attention on, the two most critical aspects of the assessment: (i) the physical, chemical, biotic or energetic nature of the perturbations, and (ii) the valued ecosystem components.

(b) A consideration of the basic linkages between the project and the structural and functional relationships within an ecosystem (Figures 9-2 and 9-3 respectively) would reveal the various possible 'interaction routes' between the initial perturbations and the valued ecosystem components.

(c) Ecological scoping can be used to determine which interaction routes offer the best opportunities for studies leading to a prediction or approximation of the changes in the valued ecosystem components, given the constraints posed by time limitations, natural variability, the state of ecological knowledge and the scientific tools available.

ken together, the above considerations, in whatever ns they might be stated, set the stage for the establishnt of an ecological strategy which would both direct the nponent tactical studies and provide a much needed sis for communication and understanding among all par; involved. Three examples are reviewed in the following tions.

'How to get the design of studies is more important han the actual design."

'Early studies usually incorporate a whole array of speies and parameters. Later studies and the monitoring rogramme can key in on the species and parameters f concern."

We have to shift the emphasis in pre-EIS studies from nassive baseline programmes to better study planning nd data interpretation."

Strategy Based on Succession

ı 1971, a major two-year study was launched to detere the effects of reduced water-levels in the Peaceabasca Delta in northern Alberta which resulted from construction of a dam on the Peace River in British ımbia in 1968 (Peace-Athabasca Delta Project Group, 3). Although the average water-levels had already been stantially lowered by the time the study was initiated, nvestigators were still faced with the difficult problem of licting future water-level alterations and the long-term cts of such changes. In that respect, the study strategy h was adopted is relevant to more conventional preect impact assessments.

was clear that the reduction in water-levels was the ırbation causing major changes in the Delta. A detailed review of hydrographic records showed that the maximum yearly water-levels in the Delta had declined significantly compared to long-term natural variation. The investigators were able to extend the hydrologic baseline back 120 years before records were kept through an interpretation of tree-ring data. With this baseline record and input-output flow data, a hydrologic model was developed which was able to simulate water-levels throughout the Delta under different flood conditions.

The major concerns were reductions in populations of a number of valued species which relied completely or partially on the extensive wetland habitat in the Delta. These species of concern were identified early in the study. They included migratory waterfowl, muskrat (which supported a local native trapping economy), bison (a rare species), moose, and four commercially important species of fish.

Preliminary investigations indicated that structural and functional characteristics of the Delta ecosystem were regulated by the normal seasonal flooding which maintained much of the vegetation in early stages of succession. A reduction in water levels was expected to alter radically the total area and distribution of habitat and thereby change the carrying capacity for the various species of interest. A general strategy was developed which involved the natural succession of vegetation as the process whereby future habitats could be predicted, with extrapolation to future populations through a determination of carrying capacity. Figure 9-4 portrays graphically our interpretation of the study strategy.

The strategy which guided the entire study effort had the following characteristics. First, it capitalized on the opportunity to make quantitative predictions of future habitats based on the *process* of natural succession and the capability to determine the relationships between water levels and various successional stages. Secondly, it discouraged attempts to predict changes in species of concern directly since the perturbation was not expected to result in direct mortality. The relationships between species abundance and available habitat were also not understood. Finally, it recognized that while carrying capacity could be determined for different habitat types based on existing conditions, the future total carrying capacity for the Delta could not be predicted directly since the extent of habitat types would change with succession.

The strategy incorporated the following tactical studies:

(a) Habitat types were mapped for the entire Delta.

(b) Population surveys of the species of concern were conducted and studies were undertaken to establish carrying capacities for the different species in the various habitat types. In the process, it was discovered that most species were underutilizing the habitat available.

(c) Studies were conducted to determine the relationship between water levels and stages in plant succession based on existing conditions.

(d) The hydrologic model was coupled with the habitat water-level relationships and used to generate future

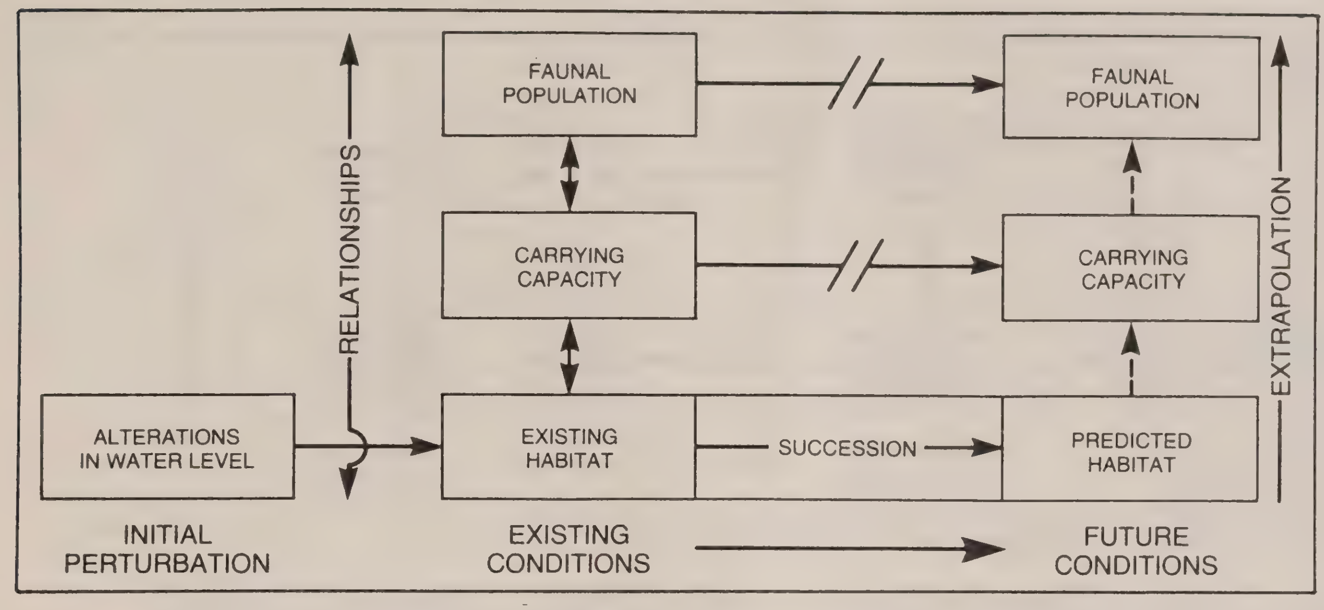


FIGURE 9-4 A STUDY STRATEGY BASED ON SUCCESSION

habitat distribution maps under different water level regimes.

(e) For the various species, total carrying capacities for the Delta were calculated based on the predicted distribution of habitat types and resulting future population levels were extrapolated.

Some of the predictions resulting from this study are presented in Table 9-2. It is both rather surprising and somewhat discouraging that some 10 years later assessment studies in general do not reflect the advantages to be gained from such an organized approach to a problem.

A Strategy Based on Bioaccumulation

As previously mentioned, the participants at one of the workshops were asked to design an assessment strategy for a planned uranium mine. Although the actual mine proposal was fictitious, it was based on a realistic scenario and credible data were provided. The results of the exercise provide another example of how a strategy based on ecological concepts can clearly direct subsequent studies.

The perturbation of prime concern was the introduction of radioactive material into the natural system as the result of discharges from the open pit mine, the tailings pond or the milling operation. It was decided to select four specific radionuclides for study as prototype toxicants based on their pathway through the ecosystem, their toxicity and their persistence. This served to reduce the study effort to reasonable limits and provided the basis for extrapolation to other radionuclides having similar characteristics.

Table 9-2

Some Projected Long-term Effects of Modified Flows in the Peace River on the Peace-Athabasca Delta (from Peace-Athabasca Delta Project Group, 1973)

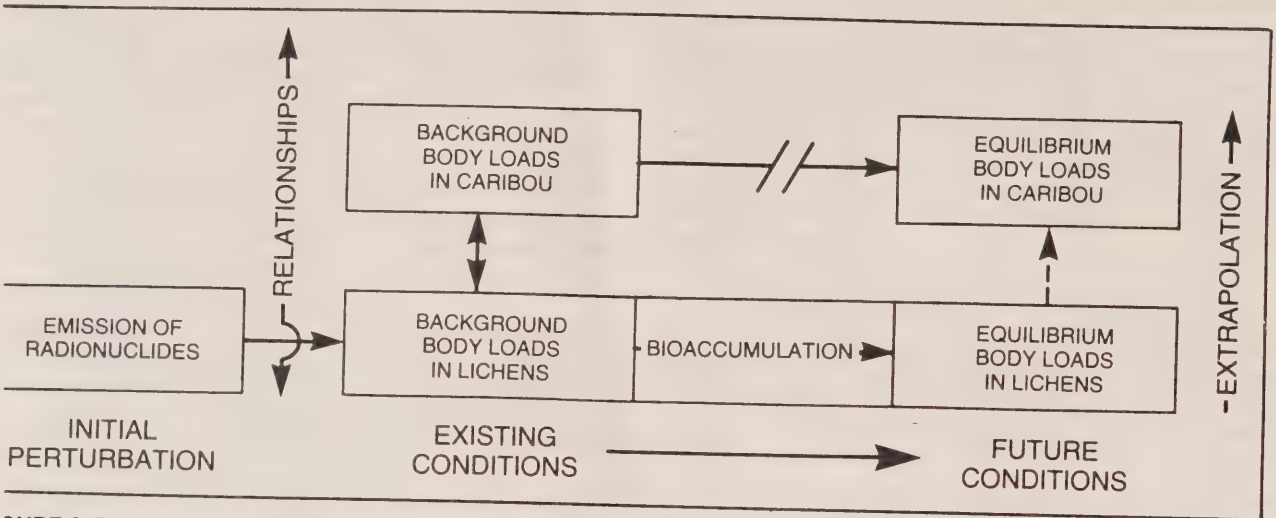
The estimated future water levels in Lake Athabasca indicate that the average summer levels will be 1.1 feet lower than those in the natural regime, and that the annual maximum levels will be 1.8 feet lower.

Because of the reduction in peak summer levels, many of the Delta's perched basins will be filled less frequently, and it is predicted that shoreline important to many wildlife species will decrease by approximately 50%.

A permanent reduction in the spread between average summer levels and average peak levels from 1.5 feet to 0.8 feet will reduce the vertical limits of the early successional plan communities important to wildlife by as much as 50%.

Waterfowl production is expected to decline by approximately 20% to 30% because of loss of suitable habitat.

The average muskrat population under the modified regime will be lower than in the past but will not average as low as during 1968-71. Decreases compared with those of the natural regime are expected to range from 41% to 66%.



GURE 9-5 A STUDY STRATEGY BASED ON BIOACCUMULATION

variables to be examined were body loads of toxi- in selected species to the extent that their reproduc- otential or food value would be impaired. The species led caribou (local consumption), muskrat (fur-bearer) ike (sport fish). These species determined the need oth terrestrial and aquatic studies. Time boundaries to be established according to the time required for receptors to reach equilibrium body loads. Spatial laries were to be set on the basis of isopleths of pre- biotic thresholds or regulated concentrations of uclides.

ecological scoping exercise revealed that it would be sible to predict accurately the equilibrium body loads ribou since their use of the area was sporadic and ore their exposure to contaminated food could not be ined. On the other hand, their main food source, , absorbed airborne radionuclides directly and it was it that equilibrium body loads could be quantitatively ed.

following study strategy emerged (Figure 9-5). The of the study would be at the individual level in the cal hierarchy rather than the population level. The process involved which offered some predictive cap- was bioaccumulation through the food chain. By ison with lichens surrounding other similar opera- quilibrium body loads of lichens at various distances e mill site could be predicted with some confidence. nilar manner, it was felt that body loads of rooted macrophytes and bottom feeding organisms could predicted. Extrapolation to the species of concern, caribou, muskrat and pike respectively, would on the degree to which the feeding functions could rmined through investigation.

trategy was characterized by the following:

was necessary to determine the potential distribu- on of radioactive material through transport and ite models to establish isopleths based on deposi- on rates.

(b) Surveys were only required to establish the distribution of initial receptors in relation to critical isopleths or to detemine if the species of concern occurred within critical isopleths.

(c) The bioaccumulation of radionuclides to equilibrium levels in initial receptors would be predicted on the basis of conditions existing at other similar projects and the research literature.

(d) Studies would be required to determine the feeding functions of the species of concern in relation to the build up of toxicants through the food chain.

Obviously the strategy was never applied; though it was interesting to observe how the participants in the workshop were able to think through the assessment and thereby begin to identify the opportunities and constraints resulting from a consideration of the ecological implications.

A Strategy Based on Eutrophication

Participants at the Brandon workshop were exposed to a comprehensive computer model known as the 'Lakeshore Capacity Simulation Model', Teleki and Herskowitz, 1982), developed by the Ontario Ministry of Municipal Affairs and Housing for the purpose of examining the environmental impacts of cottage developments on inland lakes in Ontario. The model was used in a 'gaming' mode as the participants considered the design of an environmental impact assessment for a hypothetical cottage development on the shores of Reed Lake in north-central Manitoba.

An important component of the model involved impacts on lake sport fish; in the case of Reed Lake, the species of concern was lake trout. The model was capable of examining two distinct pressures on the lake trout population, namely, fishing pressure and eutrophication of the lake. Development of the model showed that in most cases, the increase in fishing pressure resulting from improved access

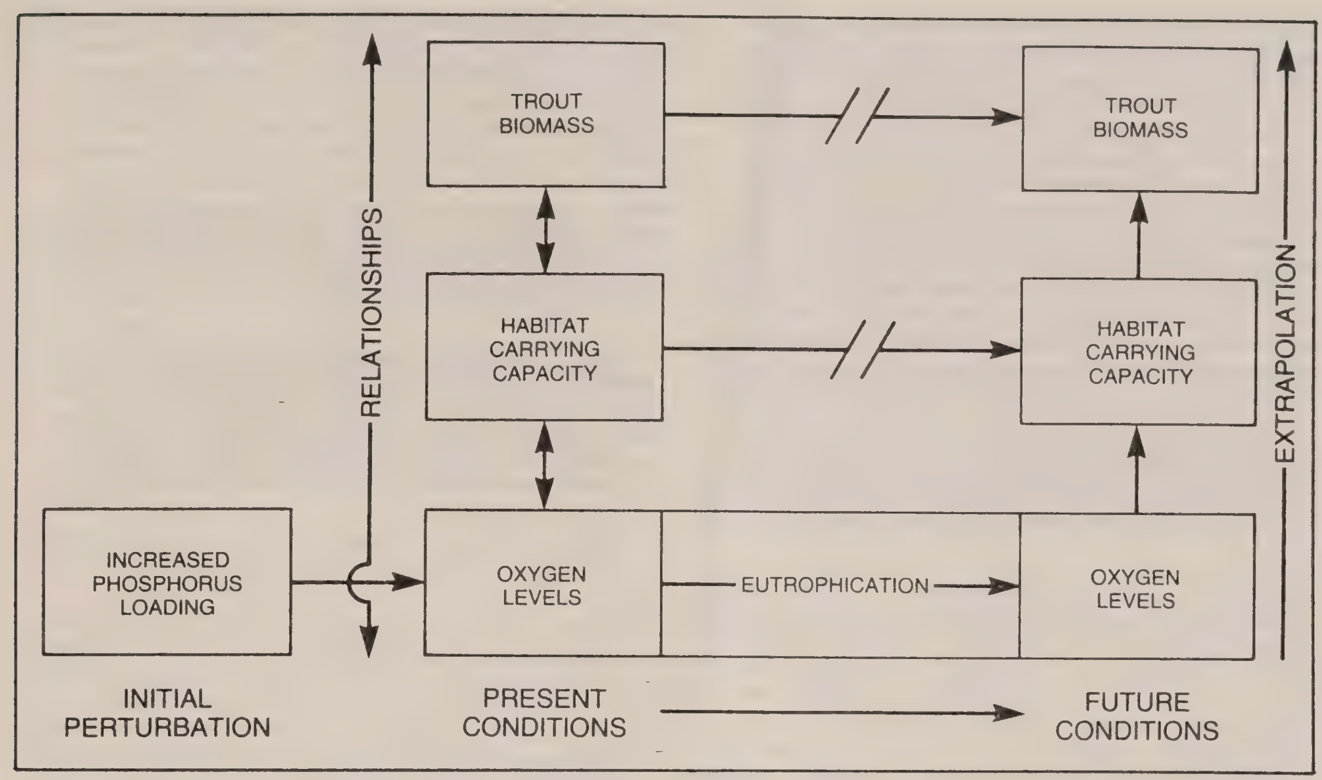


FIGURE 9-6 A STUDY STRATEGY BASED ON EUTROPHICATION

and the cottage development was a far greater menace to the integrity of the lake trout population than was the increased phosphorus loading from cottage sewage systems. However, the following discussion will pertain to the latter to show how ecological linkages and processes are key elements in predicting effects on valued ecosystem components in an impact assessment.

An interpretation of the prediction strategy is portrayed in Figure 9-6. Initially, it was necessary to examine the magnitude of the increase in phosphorus loading to the lake. In this regard, several important factors such as phosphorus loading from other sources, flushing rate of the lake, capacity of the shoreline soils to bind phosphorus, and so on, required investigation. It was recognized that the critical link between phosphorus levels and effects on the trout population was the oxygen level (or more correctly, the oxygen deficit) in the hypolimnion. This oxygen level could be translated into carrying capacity for trout which determined the maximum trout biomass that could be supported by the lake.

It is clear from the diagram that the driving force which produces an effect on trout from increased phosphorus loading is the process of eutrophication. Thus, the relationships involved in the trophic evolution of lakes must initially be used as a basis upon which to build the prediction of lake trout biomass at some future time. Only when a future oxygen deficit is predicted can the effect be extrapolated through the carrying capacity linkage to biomass.

It is important to note that the Lakeshore Capacity Simulation Model was built not for the purpose of planning a study strategy (although we acknowledged earlier that such model building can be highly useful in this regard) but rather to provide a mechanism for synthesizing (i) a diverse set of data banks and (ii) a wide range of perceptions as to how cottage developments affect lake ecosystems. Nevertheless, it is easy to visualize how this modelling effort, which recognized the ecological nature of the initial project-induced perturbation and identified the particular attributes of concern, could be used early in an assessment to provide strategic direction. In particular:

(a) The model identifies the need for data on specific physical and chemical characteristics of the lake as they pertain to phosphorus retention and subsequent processes of eutrophication.

(b) The model capitalizes on known processes for which some predictive capability has been developed.

(c) The model reflects the opportunity to forego detailed food chain analyses (see Figure 9-3) by recognizing the direct link between physical/chemical changes and the species of concern.

Concluding Remarks

Our interpretation of the strategies developed in these examples is somewhat simplified. However, our objective

has been to illustrate how even basic knowledge about the structural and functional relationships within ecosystems can be helpful in the approach to impact assessment studies if they are considered in an organized fashion. There are a number of important generalizations which can be drawn from the preceding discussions. First, it should be clear that the tactical studies undertaken will require the field scientists involved in impact assessment to apply their full range of ecological knowledge and technical skills (e.g., in the above cases, the determination of carrying capacity, feeding functions or physiological stress). Secondly, without the context of a study strategy, committed to the written record, a definite need for the results of individual studies will be less evident to all the parties involved in the assessment.

Finally, as many authors have previously emphasized, the major opportunities for developing predictive studies lie in the use of functional relationships or processes. Thus, the strategy must incorporate some reasonably well understood ecological processes within which appropriate tactical studies can be undertaken. The analytical problems posed by the strategy adopted will depend upon the complexity of the project and ecosystem under consideration. The preoccupation of many authors with the *problems* of dealing with functional relationships at a sophisticated analytical level may have caused many assessment practitioners to shy away from the idea of developing a study strategy. As a result, in general, impact assessments have not taken advantage of the direction in study design offerred by such basic considerations.

"You can extrapolate the effects of a change in a parameter only as far as that parameter controls others. In the Simpson Lagoon study, it was found that secondary production was controlled by the carbon available from primary production. However, tertiary production was not limited by the carbon available from secondary production."

10 — BOUNDING THE PROBLEM

"As a project person, how do I make a decision on what are my time and space boundaries, and what ecosystems do I investigate when the ecological relationships may be so subtle as to be completely undefined?"

"Setting the boundaries is simple — how far in space and time does the project affect the environment?"

"Our group agreed that you should begin boundary setting by looking at the extent of the project, and then adjust them on the basis of physical environment patterns."

"The spatial boundaries usually change during the course of a study — and they get bigger, not smaller."

The importance of establishing spatial and temporal boundaries for an impact assessment was discussed earlier in a general sense, including the need to consider the space and time frames imposed by natural systems. The more detailed review presented below will serve to illustrate the problems posed in setting bounds on the physical and biological components of natural systems with some examples of how such boundaries have been established in impact assessments.

PHYSICAL CHARACTERISTICS

Following an initial consideration of the boundaries imposed by administrative authority and the project itself (see Figure 8-1), the usual step in impact assessment studies is to consider a set of physical boundaries. For some projects, the physical characteristics of the ecosystem potentially impacted are so well defined that the spatial boundaries become obvious. Such was the case in the Halifax workshop when the participants considered an offshore hydrocarbon development scenario; it was assumed that the Gulf of St. Lawrence was the system under study although it was never explicitly stated. A similar situation occurred in the Peace-Athabasca Delta Project (Peace-Athabasca Delta Project Group, 1973). Presumably the topographic and vegetational characteristics of the Delta were such that the study limits were obvious, although there was no rationale given for the boundary shown on a map of the study area.

Sanders and Suter (1980) suggested that systems with relatively limited and well defined input-output transport mechanisms in operation, such as lakes or watersheds, are easy to bound compared with oceanic and atmospheric systems. In any event, it seems logical to establish initial spatial boundaries for an impact assessment on the basis of the physical transport mechanisms involved, that is, primarily the forces of wind and moving water. These mechanisms were used to establish initial boundaries for the port expansion scenario at the Vancouver workshop (the silt plume of the Fraser River) and the proposed Liard River dam at the Edmonton workshop (Liard River and the mainstem of the MacKenzie River including the delta). In the latter case, a report from another workshop dealing with the same project (Jones *et al.*, 1980) indicated that agreement on physical boundaries may at times be difficult. A controversy arose about whether the seaward boundary of the delta should have been set according to the mixing zone, the detectable limit of fresh water or the seaward limit of coarse sediment deposition.

As previously indicated in the discussion on modelling, it is common for impact assessments to refer to oil slick trajectories or air emission plumes. However, it is not always clear how the results of such exercises are used to establish or alter assessment boundaries. For example, it only became evident during interviews with those responsible for the South Davis Strait assessment that the results from more than 900 runs of an oil slick trajectory model were used to change the southern boundary of the assessment study area (refer to Appendix C for details).

Although oceanic systems present serious problems when it comes to establishing boundaries for impact assessments, there are techniques available which can be of considerable help in this regard. A case in point is the pre-operational monitoring programme currently being conducted for the Point Lepreau nuclear power plant (Smith *et al.*, 1981). Here the release of surface and bottom drifters near the site of the cooling water outfall were used to determine possible routes of dissolved or thermal contaminants and sediment-borne pollutants, respectively. The results demonstrated how careful attention to transport mechanisms, even in the same medium, can be used to advantage in establishing boundaries for impact assessments. Thus, the distribution of bottom drifters indicated that sediment-borne pollutants would tend to be deposited in an area extending to the west of the outfall. The surface drifters, however, suggested that dissolved contaminants may be carried in the reverse direction, back into the upper reaches of the Bay of Fundy along the Nova Scotia coastline.

Another criterion for establishing boundaries on physical grounds involves a consideration of areas of material accumulation, or sinks. As pointed out by a number of workshop participants, in projects involving the release of toxic materials, it is extremely important not only to understand the transport mechanisms involved but to have the site of accumulation included within the assessment boundary, although it may be some distance removed from the geographical focus of the project. This idea was strongly supported by a group of scientists looking at the environ-

ental assessment requirements for off-shore hydrocarbon velopments on Georges Bank (Anonymous, 1975). In eir words, any impact assessment would have to "resolve routes, reactions and rates involved in the passage of ntaminants or pollutants through the Georges Bank gion and the reservoirs in which they may be found."

COLOGICAL BOUNDARIES

'The establishment of a parameter's stability boundaries depends on our historical records of its natural variation."

'The real stability boundaries for populations in upper rophic levels are elusive because of high natural variaion and a lack of baseline fixes. One must either conrive artificial stability boundaries, or be satisfied with he boundaries that are easier to establish for shorterved, lower-trophic level organisms."

s pointed out by Hilborn and others (1980), ecological ndaries may not be readily evident from physical ndaries. They suggested that ecological 'connectivity' blishes boundaries for second and higher-order acts which cannot be determined on the basis of physicharacteristics alone. The participants at the Edmonton kshop soon realized that the ecological boundary for acts of the Liard River dam would have to be extended ond the MacKenzie River Delta which is itself more than 00 km from the project site. It was postulated that nges in the timing of spring breakup of ice on the delta ld affect the survival of migratory bird populations h nest on islands further north but whose breeding suc is critically linked to the timing of open water in the a.

s indicated previously, the major determinants of ecoal time boundaries are the magnitude, periodicity and ls of natural variations of the system components of est. This natural variation, in effect, defines a stability dary, that is, an ecological boundary in time. This sta boundary concept is well described by Holling and berg (1971) and Holling (1973) and also received ssion in the workshops as being a key ingredient in stem modelling for the purposes of environmental ct assessment. In essence, stability boundaries are the within which a variable should be capable of returning pre-impact state and impacts are responsible for ng variables outside of these limits. In most cases, the approximation of these stability boundaries is found in sults of long-term empirical studies.

hough ecosystems also operate within stability bound- the main focus in impact assessment has been on ation changes. Aside from normal seasonal and yearly ations in most population levels which must be cond in establishing time boundaries, biological time lags en the imposition of an impact and its ultimate sion in the dynamics of an affected population are of importance. For sublethal effects on adults, the between birth and the age of first reproduction may ent to the minimum time lag between perturbation and measurable response in the population (Fritz *et al.*, 1980). For short-lived and fast-reproducing species, this time lag would be compatible with most assessment time frames. However, the time boundary for long-lived and slow-reproducing species may have to be greatly protracted.

One of the most noticeable deficiencies in environmental impact assessments from the perspective of establishing appropriate ecological time boundaries is the lack of consideration of response and recovery times for components potentially impacted. Impact predictions often imply that once a natural system is perturbed it will not recover. On the contary, many ecosystem and population components are quite robust and have a high degree of built in resiliency (Larminie, 1980a).

An often quoted example of the recovery capability of living systems is provided by Baker (1971) regarding the recovery of oiled saltmarsh vegetation. She covered the leaves of *Spartina spp.* in test plots with crude oil 2, 4, 8 and 12 times over a period of 14 months and compared the numbers of tillers (side shoots arising at ground level) with a control plot. The results showed that the plant community, when oiled up to four times, was able to recover within about one year after an initial depression. There was a marginal recovery after 8 oilings but total elimination for 3 years after 12 oilings. Even in the latter case, data on plot recovery would be required over the longer term to demonstrate complete lack of recovery. The utility of relatively simple experiments like this in impact assessment studies is obvious.

However, it can be misleading to generalize on this topic. For example, in a comprehensive review of the environmental impacts of energy developments in the coastal zone, Hall and others (1978) noted that the oil from the Torrey Canyon disaster did not penetrate more than 3 cm into the sediments along the Brittany coast and recovery was well underway within 16 months. On the other hand, in two well-studied oil spills, one in Massachusetts and another in Nova Scotia, the oil penetrated much deeper into the sediments and damage was extensive and longer lasting. In the latter case, oil moved back into the water from the sediments for at least five years.

Unfortunately, most of the research concerning stability or resiliency within natural systems (e.g., Holling, 1973; May, 1975; Orians, 1975; Peterman, 1980; DeAngelis, 1980 and VanVoris *et al.*, 1980) has progressed little beyond the conceptual or theoretical stage with limited direct application to determining boundaries in environmental impact assessment. Indeed, it is often difficult for a reader unfamiliar with the theoretical considerations involved to understand the jargon. For example, authors may use different meanings for such terms as constancy, persistence, inertia, elasticity, amplitude, cyclical stability and trajectory stability (Orians, 1975).

Other authors such as Cooper (1976b), Westman (1978) and Cairns (1980) have focussed their attention more on the practical considerations of recoverability in damaged ecosystems. The results of a symposium on recovery pro-

cesses in damaged ecosystems (Cairns, 1980) suggested that, although the factors influencing recovery are generally known, they are best understood for freshwater ecosystems. But as Westman (1978) pointed out, even though we understand the operative factors involved in aquatic systems, they have limited application in environmental impact assessment since we can only measure actual recovery after the system has been disturbed. In other words, our knowledge of the innate properties of the system which determine recoverability have not developed to the point where prediction is generally possible.

However, there are possibilities for predicting, in a crude sense, the recolonization of systems following disturbance (Cairns and Dickson, 1980). While this is a limited interpretation of the meaning of recoverability, it has practical application in assessment studies. The authors pointed out that their ideas are not based on speculation but rather on evidence from the analysis of case studies which involved monitoring of aquatic systems before and after major disturbances.

Their approach involves the calculation of a 'recovery index' as the product of six characteristics each assigned a value of 1 to 3. The six characteristics, evaluated in the context of the particular aquatic system under consideration, are: (i) proximity of recolonization sources, (ii) mobility of propagules, (iii) physical suitability of habitat for recolonization, (iv) chemical suitability of habitat for recolonization, (v) toxicity of disturbed habitat, and (vi) effectiveness of human management structures to facilitate rehabilitation procedures. The potential for recovery is determined by comparing the calculated index with the following standard:

400+	chances of rapid recovery are excellent
55-399	chances of rapid recovery are fair to good
55-	chances of rapid recovery are poor

While such results are obviously very crude in a quantita tive sense, the authors cautioned against the temptation fo more detail since it would indicate a greater degree o refinement of the analysis than could be substantiated b our knowledge of the factors involved.

Except for limited reference to the number of generation required for full recovery following a perturbation (Imperia Oil Ltd. *et al.*, 1978), we were unable to find any exampl where the potential for the recovery of valued ecosysten components was considered in setting boundaries i impact assessments conducted in Canada. This may be reflection both of the difficulty of predicting impacts a such (let alone attempting to predict recovery rates) and o the conventional survey and inventory approach to assessment studies which essentially ignores the dynamic natur of the systems involved. The propensity for change, as reflected in variation over space and time, is the major problem in measuring or predicting impacts. But, by failing t consider the potential for recovery, we eliminate the onl chance where this dynamic characteristic might be used t our *advantage* in environmental impact assessment.

In closing this section on ecological boundaries, we len our support to the following plea from Westman (1978):

> "If scientists involved in environmental impact assessment begin to publish information on resilience in standardized ways for particular ecosystems being analyzed, we may at a future date be able to draw some generalizations about ecosystem resilience that will enable us to quantify the degree of 'irreversibility of commitment' of ecological resources more effectively."

11 — ELEMENTS OF EFFECTIVE STUDY STRATEGIES

FOR INITIAL UNDERSTANDING

"People have not asked critical questions. Baseline is the easiest thing to do — go out and collect animals. But no one has requested that information."

"We can't categorically drop all notions of baseline surveys — they may happen to be necessary for specific projects."

"Characterizing the environment is useless unless it helps in predicting project effects."

Virtually all generic and specific guidelines for environmental impact assessment in Canada include a requirement to 'describe the existing environment.' Therein lies the beginning of the problem. It is not a matter of the request being illogical; it immediately sets the stage for a diffusion of study effort as opposed to a more focussed and efficient approach. For most people involved in impact assessments, the generalized description of the environmental setting of the project constitutes the baseline data for the assessment. Presumably in their minds pre-project studies are directed towards meeting the requirements for baseline information as defined by Duffy (1979):

> ". . . a description of environmental properties and processes within a specifically defined area, taking into account the dynamic and interactive nature of ecosystems, which will allow the identification of possible environmental impacts resulting from any anticipated intrusion by man within a specified time frame to meet the requirements of environmental impact assessment."

In contrast, we agree with the more operative concept of baseline data as a statistical definition of the natural variability of phenomena of concern against which future changes can be predicted or measured (Hirsch, 1980). Even using this more explicit definition, Hirsch emphasized that baseline data in themselves do not constitute a basis for prediction. He argued that baseline studies should be preceded by an ecological characterization. The objective should be to gain an appreciation for such features as the biological resources important to man, and important components of their habitat, the key biological processes such as major trophic relationships, and driving forces such as climatic conditions and transport mechanisms. For many areas which have already been extensively studied, such a characterization might be developed mainly on the basis of available information. In other cases, particularly in frontier areas, extensive field reconnaissance may be required. Only after the results of an ecological characterization have been incorporated into a study strategy (although this may be an iterative process to some degree) should baseline studies be undertaken. At this stage, the potential range of basic ecological linkages between the project and the ecosystem will have been considered and the results of an ecological scoping exercise will have narrowed down the possible avenues for predictive studies and the need for specific information.

As might be expected, there are few examples where ecological characterization has been used in impact assessments in Canada, or at least where such an approach is evident from reading assessment reports. Precisely because of the lack of resolution provided by ecological characterization, we tend to have baseline studies in which the count everything approach prevails. There are, however, indications that the ideas embodied in the concept are gradually being adopted, although not necessarily in the context of a study strategy as described above.

In a generic sense, the application of ecological land surveys (ELS) to environmental impact assessment (Environmental Conservation Service Task Force, 1981) can be considered as a form of ecological characterization. ELS involves the delineation and description of units of land based on the integration of information on geomorphology, soils, vegetation, climate, water and fauna. Land units may be interpreted at any one of six hierarchical levels of generalization and presented in map form using scales ranging from 1:1,000,000 down to 1:2,500.

Particularly at the more generalized levels, ELS is a quick and efficient method of collecting and presenting information on the environment at a reconnaissance level. As part of an ecological characterization, the results could help to set study boundaries, identify potentially critical areas and provide a basis for planning baseline and monitoring studies. In this context, it would seem to meet one of the objectives for ecological characterization set by Hirsch (1980): "Ecological classification systems based on hierarchical concepts, combined with conceptual ecosystem modelling, should help provide a more structural approach to the definition of reasonable study boundaries." ELS at the more detailed levels is tactical in nature and appropriate for meeting specific project planning requirements.

The application of ELS to impact assessments in Canada has been reviewed by Duffy (1979) and by Eedy and others (1979). The latter authors gave a number of examples where the approach was used for various types of projects under different administrative frameworks across the country. The most comprehensive application of ELS was in support of project planning for the James Bay Hydroelectric Development which involved mapping an area of 410 000 square kilometres. A project manager's opinion of the utility of the results was given by Gantcheff and others (1979). They concluded that the ELS provided an excellent generalized data base for planning; however, its full potential in environmental impact assessment was not realized

to a lack of validated interpretation keys and insuffi-
ıt user familiarity with the basic concepts of ELS.

nother example of ecological characterization in a gen- sense, which demonstrates the approach that can and ıld be taken, is found in *Polynyas in the Canadian Arctic* ling and Cleator, 1981). The publication summarizes in organized manner the available information on the sical and biological characteristics of areas of the Arctic an which tend to remain free of ice. A general review is wed by fairly detailed discussions of specific polynyas vn to recur from year to year, including a consideration e potential importance of such areas to various Arctic ies. Such background information is extremely relevant ıe planning of northern development, and represents :ind of ecological characterization that should form the l part of any impact assessment studies.

ıe of the best examples of ecological characterization part of the Canadian-designed Simpson Lagoon-Jones ds study (Truett, 1980). The initial phase of the study, ed to as an interdisciplinary synthesis, involved a v of available information on estuaries, lagoons and ır island systems in general. The focus was on major ıtive physical processes, hydrographic characteristics estuarine biology. The generalizations thus derived compared with the major physical and biological char- stics of Arctic ecosystems as likewise described in the ure. The purpose of the exercise was to proceed from ledge of relevant systems to a consideration of the son Lagoon-Jones Islands system such that the fol-] initial question could be addressed:

the Simpson Lagoon-Jones Islands system essen- to the well-being of the key species that use it, and, ɔ, what are the characteristics of its components processes that make it so?"

have emphasized throughout this section of the that it is both necessary and helpful to initiate an t assessment with very basic concepts about the l systems involved. Figure 11-1, taken from Truett's report, illustrates the general level of conceptualiza- at could be attempted as the result of an ecological :terization. It is a graphical representation of the gen- ıderstanding that might be derived from a consider- of the basic structural and functional processes. It is ıstrative of the important contribution that ecological terization can make to the development of a general trategy for the assessment.

ıbove-noted examples of ecological characterization ıer generic in nature (i.e., not related to a specific assessment) or involve relatively well-bounded sys- As such, the application of the concept to projects g large and complex systems may be questioned. ır, the recent Initial Environmental Assessment for ırbon exploration on the Labrador shelf (Petro- , 1982) can be considered as an initial attempt to an ecological characterization for an off-shore ment. Although the results of the effort are not lirectly in time to the impact assessment, which is d to be undertaken sometime in the future, it is clear that the two activities are related, "One of the reasons for preparing this Initial Environmental Assessment is to identify the objectives and priorities for future environmental studies that directly benefit hydrocarbon development of off shore Labrador."

The Initial Environmental Assessment for off shore Labrador represents a move towards the concept of ecological characterization as a means for focussing impact assessment studies. It was stated that "the biological data will probably supply the baseline data for those biota most vulnerable to oil spills." The assessment also is noteworthy for providing the following directions for the subsequent environmental impact assessment:

(a) the assessment will concentrate on key species on the basis of their ecological dominance, rarity, economic importance and sensitivity;

(b) a reasonably precise definition is given for the significance of impacts based on reductions in populations and the time required for recovery;

(c) future studies on physical and biological interactions will be designed so that the results will contribute to the prevention or control of pollution;

(d) the need for repetitive, replicate sampling to statistically define the spatial and temporal variability of measured variables is acknowledged; and

(e) the necessity for long-term monitoring based on variables that are reliable indices of environmental change is recognized.

This ecological characterization also provides an example of the beginnings of a study strategy. In this sense, the cod larvae study recommended for implementation if an assessment were required is centred around the impacts of oil on Atlantic cod, the most important commercial species in Labrador waters. A study based on determining the distribution and movements of cod eggs and larvae was suggested to determine the potential for exposure to oil in the event of a major spill. The strategy would include a project to develop a technique for determining if eggs and larvae were exposed to oil. In addition, regional physical oceanographic and meteorological data as well as biological information on lower trophic levels would be collected incidental to the cod study. In the words of the assessment, "The cod larvae study would be closely coordinated with regional physical oceanographic studies to provide the information necessary to interpret the movement of eggs and larvae, and to minimize costs through logistic coordination."

IN SUPPORT OF PREDICTION

Learning from other Projects

"Since experiments take so much time and money, we should concentrate effort on case studies."

"Much more use and emphasis has to be placed on case studies for developing predictive confidence."

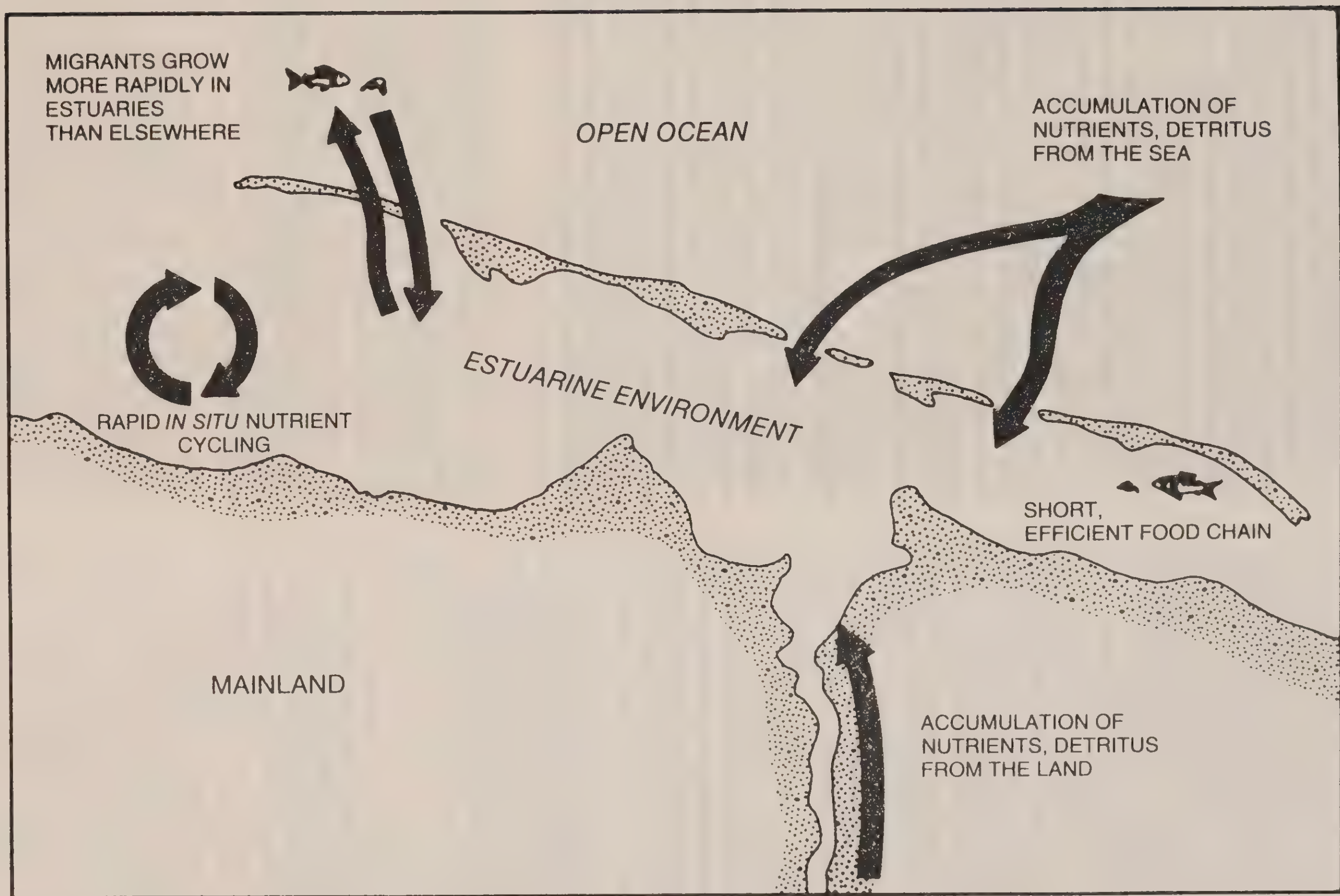


FIGURE 11-1 FACTORS CONTRIBUTING TO HIGH PRODUCTIVITY IN A MARINE LAGOON (FROM TRUETT, 1980).

The workshop participants and the publications made reference to substantial advantages for prediction to be gained from studying the results of previous projects of a similar nature. There are, however, two basic constraints involved in such an approach:

(a) It may be impossible to determine pre-project conditions at the site of the earlier development because of the absence of baseline studies.

(b) It may be inappropriate to extrapolate from the impact of one project to the potential impact of another because of the lack of a measure of the calibration between the environments involved.

Despite these limitations, case studies nevertheless may represent a reasonable basis for predicting future events. Given the logical advantages, it is somewhat surprising, as well as discouraging, to see the limited use made of this approach in impact assessment studies. While it is common for those involved in such studies to draw upon their general knowledge of previous projects or published material based on it, it is unusual for field programmes to examine such projects. Our review of environmental impact assessments uncovered the following few examples.

The Peace-Athabasca Delta Project (Peace-Athabasca Delta Project Study Group, 1973) made reference to an evaluation of drained wetlands in northern Saskatchewan. The results of this study were subsequently used to establish the general time frame required for succession to progress from exposed lake bottom to willow stage (10-15 years).

For the environmental assessment of the Lower Churchill Project Generation Facilities (Lower Churchill Development Corporation Limited, 1980), studies of mercury contamination in fish in the Smallwood Reservoir, upstream from the project, were undertaken. On the basis of these studies, mercury contamination in the lower reservoirs was not expected to be serious.

As part of the review of the impact assessment for the Alaska Highway Gas Pipeline Project (Foothills Pipe Lines (South Yukon) Ltd., 1979), the proponent prepared a number of addenda to the EIS. One of these included a report on the potential for exploitation of the fish and wildlife resources of the Yukon as a result of the project (Foothills Pipe Lines (South Yukon) Ltd., 1981). The document included a review of an Alaskan study in which fish and wildlife harvest data were analyzed to determine the effects of the influx of people associated with the Trans-Alaska Oil Pipeline. In this case, the problems and results of the American experience were considered to be relevant to the situation in the Yukon and conclusions were drawn concerning exploitation, regulations and monitoring.

Part of the pre-project monitoring programme for the Point Lepreau Nuclear Generating Station (Smith *et al.*, 1981) included a resampling of subtidal and intertidal benthic organisms along transects which had been established six years earlier to determine the effects of the cooling water outfall for the nearby Coleson Cove Thermal Generating Station. This information was considered to be, "relevant to possible changes which might be induced in ecological parameters by thermal discharges from the Point Lepreau NGS." The results of the survey indicated that ecological changes had occurred, but it was not possible to determine whether they had been caused by the thermal discharge or were related to the general progressive degradation which was occurring along the coastline as a result of pollution and dredging. In either case this information will be important in the interpretation of the results from future monitoring of the Point Lepreau project.

The workshop participants raised two other specific examples where studies of other projects could prove helpful. First, they suggested that, in considering the possible effects of Beaufort Sea dredging on marine life, the impacts of many years of dredging in the Fraser River estuary should be reviewed. In the second case, the participants at one workshop, in considering the potential impacts of a uranium mine, relied heavily on the possibility of being able to measure the body loads of radionuclides in lichens at various distances from existing mining operations.

Pre-Project Experiments

The workshop participants recognized the benefits to be derived from conducting pilot-scale perturbation experiments. However, that we could find little evidence from reviewing Canadian impact assessments where such experiments had been conducted. It would have been possible to present a number of examples drawn from the research writings; though we believe that the simplicity and predictive utility of the following example from a Canadian impact assessment illustrates well the advantages to be gained from such an approach.

As part of the studies undertaken for the impact assessment of the Donohue-St. Félicien kraft pulp mill in northern Quebec, a number of fisheries experiments were undertaken (Eedy and Schiefer, 1977). It had been determined early in the assessment that land-locked salmon, or ouananiche, were a species of concern to both regulatory agencies and the general public. As a result, high priority was given to "predictive research with unique experiments in modelling pollution dispersion and assimilation, simulation of expected effluents, fish behaviour and toxicity bioassays with simulated effluent."

The general experimental approach involved three basic elements. First, aerial and ground surveys of the river indicated that the great majority of spawning and rearing habitats for ouananiche occurred upstream of the proposed site for the mill effluent discharge. The conclusion was that the effluent would not result in physical or chemical impairment of habitat or pose a threat to the sensitive egg and juvenile stages. It could, however, prevent the adult fish from reaching their spawning areas through direct toxicity or through avoidance behaviour.

Although extensive information is available on the reaction of Atlantic salmon to pulp mill effluents, there was a concern that the closely-related ouananiche were physiologically and behaviourally different. Therefore, the second

element involved the design of experiments to determine the extent to which ouananiche would be affected by various concentrations of the expected effluent. Using water from the river and simulated pulp mill effluent based on the proposed design of the mill, bioassay tests were conducted using ouananiche, rainbow trout (to comply with government regulations covering toxicity tests) and Atlantic salmon (as a control species for which abundant toxicity data are available). Three invertebrate species which were important food for ouananiche were also involved in the tests. The results of the trials indicated that no toxicity problem would exist outside of the immediate mixing zone. As a refinement to the experiment, the trials were rerun using heated effluent, with similar results.

The third element in the experimental approach was designed to determine if the effluent would cause an avoidance reaction even though it was not toxic to the fish. To this end, drogue, dye dispersion, bathymetric and current meter studies were conducted at the proposed effluent discharge site. The results were used to determine an optimal diffuser design and location. Unique avoidance reaction experiments involving ouananiche and rainbow trout demonstrated no avoidance or preference reaction at the highest concentrations of effluent expected from the mill.

The results of the experiments demonstrated quite conclusively that the adult ouananiche would not be prevented from going past the site of the mill effluent diffuser to reach their spawning habitat, nor would the effluent affect juvenile stages of the species in the river. And these predictions were made without undertaking expensive and time-consuming surveys to determine the distribution and abundance of the species of concern!

FOR HYPOTHESIS TESTING

"EIA should be concentrating on finding out the impacts of a project so future projects can be better planned in an environmental sense."

At the time this project was initiated, there was a growing realization that impact assessment should be considered as a series of basic, sequential steps. Thus, an initial baseline data collection programme would be used to characterize the pre-project state. Cause and effect studies would then be undertaken to predict how state variables will change as a result of the project activities, and, following start-up of the approved project, monitoring would be used to determine actual impact conditions. This was the sequence of events which defined the process of impact assessment for the purposes of this project (Figure 11-2a). The major change from earlier thinking was the interdependence of the steps involved throughout the process and the recognition of monitoring as an equally important step in the overall assessment process.

What emerged during the first few workshops was a translation of these simple steps into a basic paradigm of impact assessment as viewed by applied scientists (Figure 11-2b). Thus, baseline studies would be directed towards establishing statistically valid descriptions of selected environmental components prior to the onset of the project under consideration. Subsequently, an effort would be made to predict the extent to which the values would change as a result of the project. The project may or may not proceed, in its original or altered form, depending on the reliability and acceptability of the predicted changes. In the event that the project proceeded, baseline variables would be remeasured during project construction and operation to determine the extent to which the predicted changes had occurred. In the schematic of Figure 11-2b it is important to note the continuity of selected variables from baseline studies through the monitoring programme.

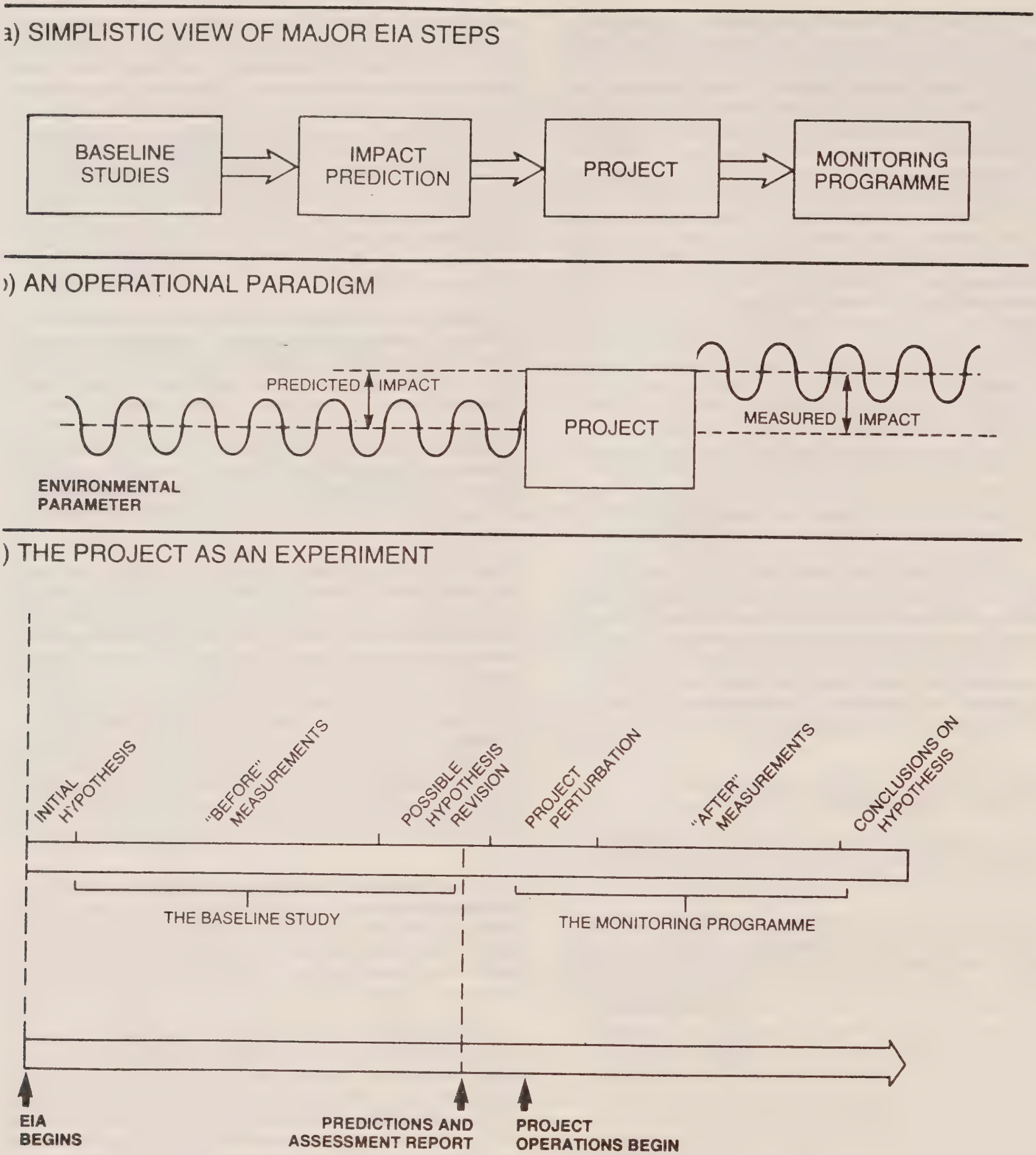
This may be a simplistic and narrow view of environmental impact assessment. Nevertheless, although it can take on the most elaborate facades (depending on the complexity of specific projects) this paradigm represents the conceptual framework within which most applied scientists involved in impact assessment studies operate. Thus, regardless of the stage in the planning process in which it is implemented, environmental impact assessment involves implied or explicit predictions of changes in environmental attributes resulting from one or more project configurations or alternatives.

Even the most optimistic applied scientist, using the best tools of the trade, will still recognize our very limited capability to predict ecological changes arising from proposed actions. As a result, there is a growing conviction that development projects must indeed be considered in an experimental context in which operational-phase monitoring is conducted to determine project effects. This is the only concept of impact assessment in which the interdependencies of the various activities become coherent in a scientific sense (Figure 11-2c). The underlying theme is that an impact assessment is not complete until the results from monitoring are available. Such monitoring unequivocally *must* take place in order to test impact hypotheses and predictions.

A few assessments are currently underway or planned which are based on an experimental approach. Although their design may not match the refinements illustrated in Figure 11-2c, they are beginning to bridge the gap between conventional impact assessment and applied ecological research.

The first example was referenced in one of the workshops. Reportedly, an impact assessment conducted for a major causeway to be constructed on the north coast of Alaska recognized the lack of understanding on which to make a reasonable prediction about disruption to the coastal ecosystem. A decision was made to proceed with the structure on the basis that it would be studied in an experimental sense to provide valuable information for future proposed activities of a similar nature.

The assessment for the Point Lepreau Nuclear Generating Station (Smith *et al.*, 1981) incorporates a long-term monitoring programme on the effects of radioactive, thermal and chemical releases from the plant. Although the baseline studies which have been conducted over the last



URE 11-2 EVOLUTION OF IMPACT ASSESSMENT PARADIGMS.

few years are an afterthought of the actual assessment process, they are *designed* to be continued well into the operational phase of the plant with the specific objective to measure changes from background conditions. In the context of the definition adopted in this report, they are true baseline studies. The Point Lepreau project also underlines another timing aspect which is often overlooked in impact assessment. The formal assessment was completed in 1975, but the plant began operation only in 1982. This would have allowed seven years for baseline studies, in addition to whatever pre-assessment studies were undertaken. Although the current baseline programme has only been ongoing since 1979, it still shows how important protracted construction times can be when the assessment process is considered in a broader time frame.

The last case illustrates an example introduced earlier in which the impact assessment studies were designed within the concept of the project as an experiment, that is: (i) it was clear from the beginning that potentially important impacts could not be predicted with reasonable accuracy or reliability, (ii) there was an early commitment to continue the studies until the effects of the project could be determined, and (iii) it was recognized that the results of the experimental studies would have direct application in other projects of a similar nature. The example is a comprehensive study undertaken as part of the environmental impact assessment for the Upper Salmon Hydroelectric Development (Newfoundland and Labrador Hydro, 1981a). The proponent acknowledged the inability to predict the effects of the project on three local caribou herds and, with the cooperation of the Newfoundland Wildlife Division (Mahoney, 1980), a study was designed to embrace six years of data collection beginning two years before project construction and continuing on for two years after operation commences.

Specifically, the hydroelectric project lies directly on an historical caribou migration path between winter and summer ranges with important calving and post-calving areas in the immediate vicinity. The concern arose about whether the project might interfere with annual migration to the extent that the status of the herds may be jeopardized.

The first year studies were the most comprehensive. Both spring and winter censuses were undertaken for the three herds using a combination of block and strip census techniques. Extensive aerial observations were then used to allow detailed documentation of herd structure. Radio collars were attached to approximately 100 caribou which were tracked throughout the year. An interpretation of the data provided an indication of the migratory habits and various behavioural characteristics of the herds.

The radio-collaring programme will continue for a number of years with a smaller number of animals. Once complete, the study is expected to demonstrate if the construction and presence of the hydroelectric project have interfered with established patterns of caribou behaviour that could possibly translate into a substantial decline in the size of the herds.

The proponent initiated another study which is complementary to the investigations described above in that it provided field observations of caribou responses to particular project elements and activities such as blasting, vehicular traffic, physical structure, and so on. It became obvious during the initial stages of the assessment that any prediction of impacts on caribou would be tentative at best without specific knowledge of such interactions. The study focussed especially on the very vulnerable post-calving stage when does and calves move through the project area. The study provided information on caribou 'time budgets' (that is, proportions of time spent in various activities), cow-calf interactions and alarm reactions in relation to the construction activities of the project.

It appears that much of the motivation for the study was a conviction by both the proponent and the government agency that the results would be essential for (i) improving the prediction of effects of future hydroelectric developments on caribou in the province and (ii) designing more effective mitigation strategies.

Part III

Opportunities for Change

12 — REQUIREMENTS FOR ORGANIZING AND CONDUCTING ECOLOGICAL IMPACT STUDIES

This chapter contains a basic set of requirements for impact studies in support of environmental assessment. The need for standard requirements was widely recognized among participants at the regional workshops and many have called upon this research project to provide such guidance. Based on our interpretation of discussions at the workshops and other inputs, the following set of requirements was developed to reflect expectations which are well within the grasp and capabilities of the environmental assessment community in Canada.

The requirements are based on a number of fundamental premises and assumptions which are very important to their application. First, they were structured so as to be implementable within all impact assessment processes in Canada. None of the requirements are so peculiar that their application should be constrained by any particular administrative or review mechanism. Secondly, the requirements are applicable to the planning and conduct of ecological studies in support of impact assessments for all types of projects in all geographic areas across Canada. These two levels of generality were considered necessary to ensure common applicability to all impact assessments conducted in Canada.

The concepts addressed in the requirements remain very simple, yet are open-ended with respect to the degree of complexity or expansion to which they can be taken. In other words, they provide considerable latitude for elaborating the concepts to any level of sophistication that suits the particular project, environment, or persons involved.

We have also limited the requirements to very basic scientific considerations. It was tempting to include a host of other, more specific topics as discussed in previous chapters of the report; the temptation was resisted for a number of reasons. First, the more specific the requirement, the less likely it will be applicable in all assessments under all administrations. Secondly, the concepts embodied in the requirements are appropriately considered in planning and designing the ecological component of an assessment. These early activities are critical to the integrity of the entire assessment, and scientific improvements are most effectively realized at this stage. Finally, by remaining at a conceptual level, practitioners are allowed maximum flexibility to practice imaginitive, rigorous science in pursuit of the assessment objectives. The requirements established here provide the impact assessment context within which such science should take place.

As impact assessment currently is practiced, there is little apparent recognition of the limitations operating on the assessment activities. The requirements, when adopted, should force all the limitations and constraints that pertain to the ecological aspects of the assessment to become transparent early in the process. Only then can one determine what realistically can be achieved through ecological study and predictive analysis.

The requirements should be viewed as representing the minimum substantive content for ecological impact studies. They should be adopted as binding, not optional. Proponents and consultants should be expected to meet the requirements as they conceptualize and plan assessments and component studies. Reviewers should use the requirements as a general framework for judging the scientific acceptability of the environmental assessment. Adoption of the requirements in this respect will not preclude the need for reviewers to critically examine the details of study design and data interpretation within the particular assessment in question. However, this task will undoubtedly be facilitated under the umbrella of the more general ecological requirements.

Unsuccessful attempts to apply any of the requirements do *not* reflect an unacceptable assessment from an ecological point of view; they reflect immutable constraints within which the assessment must take place. Thus, all parties can gain an early appreciation of the limitations operating on the assessment and can either accept them or attempt to overcome them.

The requirements should find expression in the two elements of environmental assessment common to most administrative processes, namely, the guidelines and the assessment report. We suggest that the requirements should not replace impact assessment guidelines (for indeed, the guidelines pertain to the whole assessment, whereas the requirements as set below pertain to the role of ecology in impact assessment), but rather should form an integral part of those guidelines. Admittedly, the adoption of these requirements will necessitate some fundamental reorganization and refocus in some of the sets of guidelines currently used in Canada but this is not expected to be a major obstacle in adopting the requirements.

Regard for the requirements should also be expressed in the assessment report (or the so-called environmental impact statement). Authors of such reports should present evidence that attempts were made to meet the requirements, and to present the results of such efforts, successful or not. Thus, anyone who reviews the report would have a common basis for beginning to judge the scientific adequacy of the impact assessment.

The reader should consider the requirements within the context of the entire report. It will be noted that the requirements do not explicitly deal with many of the principles, techniques and approaches discussed in detail throughout the report. We consider such principles and approaches to

'e great potential to contribute to an upgrading of the ›logical basis of environmental assessment; practitioners ɹld do well to make maximum use of them in designing ł conducting assessments. Nonetheless, it would be easonable to set such detailed considerations as uirements of all assessments. The discretion of those ɔ are planning and reviewing an environmental impact essment should predominate in determining the most ›ropriate combination of ecological principles and ›roaches for that particular assessment.

hus, the report differentiates between concepts that are ional but extremely valuable when incorporated into an logical impact assessment and those which we believe uld become mandatory exercises in all assessments. requirements listed below reflect the latter.

he universal application of these impact study require-ıts would represent a major but attainable step towards logical improvements in environmental impact assess-ıt in Canada. Adoption of the requirements does not essarily imply a new advanced level of sophistication in ertaking an assessment; it implies an effort at planning assessment similar to the organized effort that goes into ıning the project itself.

CILITATING IMPLEMENTATION

ow can basis set of criteria for conducting environmen-npact assessments be implemented? Since the require-its which follow will serve little purpose if they are not iied, the question of an appropriate means of ementation becomes crucial to the outcome of this arch project.

is not enough to say that the requirements should be ɔted by the key groups participating in an impact ssment; this gives no indication of *how* they should be ł. Nor is it sufficient simply to have the requirements rporated into assessment guidelines since such require-ts will need a scientific interpretation appropriate to ı individual assessment. The best chance for implemen-n lies in having the requirements form the basis for joint ning of the impact assessment between proponents the government agency administering the assessment w process.

I such agencies in Canada are urged to establish a core p of technical advisors for each impact assessment rtaken. The group would be expected to work with the onent's scientific staff and consultants in developing a ally agreeable design for the assessment *before* the dual studies are undertaken. This degree of co-opera-will undoubtedly be criticized by those concerned with taining an arm's length philosophy on the part of the cies administering assessment procedures. By the token, if we continue to consider co-operation as ərsion, then there is little to do except develop longer nore complex guidelines.

ə core group of advisors would be important partici-; in the final technical review of the assessment. In the event that the agreed assessment design was changed or not followed by the proponent, the core group would require justification. It would also be in a position to advise the review agency on the validity of the proponent's interpretation of the study results, a key factor in the process of impact assessment. The importance of the perceived independence and credibility of the government agency will have to be weighed against the pressing requirements to obtain the most reliable scientific data and advice possible. Obviously, some degree of compromise is necessary. In any event, it will always be the responsibility of the review agency to interpret the final results of the assessment and makes its decisions thereon.

One of the most important roles for a core advisory group would be to work with the proponent in developing an appropriate monitoring strategy and to assist the review agency in interpreting the results of, and limitations on, a monitoring programme.

In summary, the following Requirements for Organizing and Conducting Ecological Impact Studies could form the general framework within which the detailed plans for an impact assessment are worked out co-operatively by the core group of advisors to the agency and the scientific staff and consultants of the project proponent.

THE REQUIREMENTS

Requirement to Identify the Valued Ecosystem Components

It is impossible for an impact assessment to address all potential environmental effects of a project. Therefore, it is necessary that the environmental attributes considered to be important in project decisions be identified at the beginning of an assessment. This will normally require some form of public consultation or social scoping exercise to determine the values attached to various ecosystem components. Both the views expressed by the general public and those of the professional community should be considered when determining these values.

Based on the results of the scoping exercise, proponents and reviewers will have to agree on an initial set of valued ecosystem components for the assessment. Studies would subsequently be designed to investigate potential changes in these components. It is recognized that further concerns may be identified and studied as the assessment proceeds.

Experience indicates that without the early identification of valued ecosystem components, an environmental impact assessment will have little obvious direction, and the resulting diffusion of effort will lead to equivocal evaluation of important factors.

ENVIRONMENTAL IMPACT ASSESSMENTS SHOULD BE REQUIRED TO IDENTIFY AT THE BEGINNING OF THE ASSESSMENT AN INITIAL SET OF VALUED ECOSYSTEM COMPONENTS TO PROVIDE A FOCUS FOR SUBSEQUENT ACTIVITIES.

(a) A variety of mechanisms may be appropriate for developing a set of valued ecosystem components. A social scoping exercise in which all interested parties are given an opportunity to submit opinions and suggestions is recommended. The means and criteria used in selecting the valued ecosystem components should be explicitly stated.

(b) The extent to which predicted changes in the valued ecosystem components are expected to influence project decisions should be made clear.

Requirement to Define a Context for Impact Significance

Every assessment utimately focusses on the question of whether the predicted impacts are significant. Objective criteria for determining impact significance will reduce misunderstandings when an assessment is reviewed and can greatly facilitate study planning if developed early in the process. With no criteria nor context for judging impact significance, participants in the assessment process can adopt any interpretation according to their own objectives.

Three interpretations of impact significance have been identified for environmental assessment purposes: (i) statistical significance (related to problems of isolating project-induced changes from natural variation), (ii) ecological considerations (related to the importance of project-induced changes from a purely ecological perspective, independent of social values), and (iii) social importance (related to the acceptability of project-induced changes in valued ecosystem components). An overriding consideration is the degree to which project-induced changes are expected to affect project decisions.

The comprehensiveness and complexity of the criteria used to define impact significance do not determine their adequacy. Simple definitions may suffice.

ENVIRONMENTAL IMPACT ASSESSMENTS SHOULD BE REQUIRED TO DEFINE A CONTEXT WITHIN WHICH THE SIGNIFICANCE OF CHANGES IN THE VALUED ECOSYSTEM COMPONENTS CAN BE DETERMINED.

(a) Criteria for impact significance should reflect statisitical, ecological and social interpretations of the concept. Statistical interpretations should recognize difficulties in detecting project-induced changes in valued ecosystem components. Ecological criteria may include important natural processes such as primary production, and important ecosystem components such as major prey species. Social importance criteria may reflect a wide range of perspectives on the values attached to various ecosystem components.

(b) Terms used to describe the significance of project-induced changes in valued ecosystem components (e.g., major, short-term, regional) should be unambiguously defined. If they can not, reasons should be given. Such terms are subject to a wide range of interpretations in the absence of clear definitions.

Requirement to Establish Boundaries

The importance of identifying time and space boundaries early in an environmental assessment is widely recognized. Such boundaries are critical to study design, the interpretation of results, the prediction of impacts, and the determination of impact significance. Four categories of boundaries should be considered, including: (i) administrative boundaries (time and space limitations imposed for political, social or economic reasons), (ii) project boundaries (time and space scales over which the project extends), (iii) ecological boundaries (time and space scales over which natural systems function, and (iv) technical boundaries (the limitations imposed by the unpredictability of natural systems and by our limited capabilities to measure ecological change).

Different sets of boundaries may apply for different ecosystem components within the same assessment. Normally the administrative and project boundaries are identified before the ecological and technical limits are established. The constraints and limits as embodied in this broad interpretation of the concept of boundaries must be clearly set out and agreed upon as early as possible in an environmental assessment.

ENVIRONMENTAL IMPACT ASSESSMENTS SHOULD BE REQUIRED TO SHOW CLEAR TEMPORAL AND SPATIAL CONTEXTS FOR THE STUDY AND ANALYSIS OF EXPECTED CHANGES IN VALUED ECOSYSTEM COMPONENTS.

(a) An assessment should acknowledge first the boundaries imposed for administrative reasons, and the consequent limitations on the utility of the assessment. Examples include multiple political jurisdictions and trans-boundary pollution problems.

(b) Within the administrative constraints, an assessment should identify the temporal and spatial limits as dictated by the project proposal. Examples include the duration of construction and operation phases of the project, and the spatial extent of physical structures and transportation corridors.

(c) Ecological boundaries are normally considered in relation to administrative constraints and project limits. In a spatial sense, ecological boundaries should reflect, among other things, transport mechanisms and migration. Temporally, they should reflect the response and recovery times of affected systems. Attention should be given to the level of resolution at which various ecosystem components are studied within the designated boundaries.

(d) There are technical constraints to meeting the desired objectives for the assessment apart from the administrative, project and ecological boundaries. Two examples of technical constraints include difficulties in undertaking adequate sampling programmes for some species, and difficulties in predicting changes in poorly understood ecosystem components.

Requirement to Develop and Implement a Study Strategy

More than any other single factor under the control of the investigator, the use of an overall study strategy is most critical to the effective deployment of time and resources in ecological assessment studies. Development of a study strategy will greatly assist the process of refining a general concern for a valued ecosystem component into a specific question which can be answered through detailed study. Study strategies could provide a suitable basis for early formal review in an environmental assessment and may facilitate the communication of assessment results in professional and public forums.

The development of a study strategy should proceed from a conceptualization of the project and the valued ecosystem components, through an analysis of how interactions between the project and those components can be investigated, to the selection of appropriate tactical study options. Thus, apart from reconnaissance investigations which may be needed to provide some early, preliminary understanding of the natural environment, study strategies must be in place before field or laboratory studies begin.

ENVIRONMENTAL IMPACT ASSESSMENTS SHOULD BE REQUIRED TO DEVELOP AN EXPLICIT STRATEGY FOR INVESTIGATING THE INTERACTIONS BETWEEN A PROJECT AND EACH VALUED ECOSYSTEM COMPONENT, AND TO DEMONSTRATE HOW THE STRATEGY IS TO BE USED TO CO-ORDINATE THE INDIVIDUAL STUDIES UNDERTAKEN.

(a) A study strategy should incorporate a conceptual outline of the proposed project in an ecological setting, as well as conceptual views of ecological structure and function within the receiving environment. This conceptualization would explore the linkages between the project and the valued ecosystem components through suspected cause and effect relationships.

(b) A process of ecological scoping should be used to determine the possibilities for investigating ecological changes. If an interaction between the project and a particular valued ecosystem component is expected, the assessment should first explore how the interactions might be studied directly. If necessary, indirect avenues of study should be examined. Should the study and analysis of changes in certain valued ecosystem components be considered impossible, the assessment may resort to the study of relevant indicator components.

(c) Detailed studies are designed as a final stage in developing a study strategy. The assessment should make clear how every individual study undertaken contributes to the implementation of the study strategies developed.

Requirement to Specify the Nature of Predictions

In many respects impact assessment is equivalent to impact prediction. To be most useful, predictions must: (i) fulfil the environmental assessment objective of contributing to informed decision-making, (ii) contain an estimate of the uncertainty expected, and (iii) be testable through a monitoring programme. Predictions which amount to vague, generalized speculations are of little value in any of these contexts. Much more detail on the basis for predictions and on the qualifications attached to predictive statements is required.

Predictions may legitimately be based on any combination of speculation, professional judgement, experience, experimental evidence, quantitative modelling, and others. It is important that the predictive analysis make explicit the basis upon which the predictions are made.

The general capability for predicting ecological events is recognized as being weak — changes in physical variables are much more readily predicted in a quantitative sense than are changes in biotic variables. In view of this, predictive statements should be accompanied by a discussion of the limitations of the analysis.

ENVIRONMENTAL IMPACT ASSESSMENTS SHOULD BE REQUIRED TO STATE IMPACT PREDICTIONS EXPLICITLY AND ACCOMPANY THEM WITH THE BASIS UPON WHICH THEY WERE MADE.

(a) The predictive analysis should strive to ascertain the nature, magnitude, duration (timing), extent (geographic distribution), level of confidence, and range of uncertainty of the predicted changes. Reasons should be given if any of the above cannot be ascertained.

Requirement to Undertake Monitoring

The need for monitoring of ecological change is well established — we must have some degree of ecological investigation during the construction, operation and abandonment phases of development projects if we are to improve our capabilities in impact prediction and assessment. More specifically, monitoring of impacts is required to (i) test impact predictions and hypotheses, thus contributing to the body of knowledge for future assessments, and (ii) test mitigative measures, thus ensuring the protection of valued ecosystem components.

From a scientific point of view, ecological monitoring plays a crucial role in overall study design. Baseline studies, predictions or hypotheses, and monitoring of effects are all required for even semi-conclusive statements to be made about changes in valued ecosystem components.

Programmes for monitoring the effects of a project must be well defined and focussed to prevent the concept from becoming an excessive drain on time and money resources.

It is recognized that predicted changes in certain valued ecosystem components may not require monitoring following project initiation. Thus, the time and resources available for monitoring can be concentrated on changes in those components most poorly understood or most critically in need of protection.

ENVIRONMENTAL IMPACT ASSESSMENTS SHOULD BE REQUIRED TO DEMONSTRATE AND DETAIL A COMMITMENT TO A WELL DEFINED PROGRAMME FOR MONITORING PROJECT EFFECTS.

(a) The design of a monitoring programme should b part of the development of a study strategy for an valued ecosystem component. Thus, baseline stud ies and predictions would be designed so that con clusive statements could be made once the monitor ing studies are complete.

(b) An assessment should make absolutely clear th need for the results and the expected duration of th monitoring studies. The programme should remai flexible enough to be adjusted as appropriate t meet its objectives.

13 — RECOMMENDATIONS

In addition to the Requirements for Organizing and Conducting Ecological Impact Studies, the research project has identified several other initiatives which would facilitate and encourage a more scientific approach to environmental impact assessment. The following recommendations pertain to the administrative and institutional aspects of impact assessment.

Recommendation 1 — Adoption of the Requirements

Implementation of the Requirements for Organizing and Conducting Ecological Impact Studies is expected to occur mainly through assessment guidelines or terms of reference. However, successful application of the requirements will not occur unless they are endorsed by all the parties associated with the environmental assessment process, especially the review agencies, proponents, consultants, and professional organizations. The requirements must be widely accepted and must be seen to contribute to an improved scientific basis for impact assessment.

IT IS RECOMMENDED THAT ALL GROUPS ACTIVELY INVOLVED IN ENVIRONMENTAL IMPACT ASSESSMENT ADOPT THE REQUIREMENTS FOR ORGANIZING AND CONDUCTING ECOLOGICAL IMPACT STUDIES.

(a) Agencies that administer impact assessment procedures should incorporate the requirements into their policy documents and into assessment guidelines which they issue. As well, technical advisors should be requested to take the requirements into account when reviewing assessment studies.

(b) Project proponents should advise their environmental staff and consultants to adhere to the requirements when planning and undertaking assessment studies.

(c) Professional organizations and industrial associations should advocate the requirements as performance standards for their members involved in assessment studies and should encourage their use as a basis for further study and elaboration by the professional community.

(d) Environmental consultants could use the requirements when preparing proposals to undertake assessment studies, and should adhere to them when designing and conducting such studies.

Recommendation 2 — Agency Advisory Committees

This research project benefited from the contributions of a scientific advisory committee composed of individuals from university, industry, government and the consulting community. The committee periodically reviewed the results of the project and advised on future activities.

Agencies that administer assessment procedures often do not have the expertise needed to deal with scientific matters related to environmental assessment. The concept of a scientific advisory committee should be of interest to such agencies. The committee could provide unbiased advice on numerous matters related to scientific practice in impact assessment, and other matters in general support of the assessment process.

IT IS RECOMMENDED THAT AGENCIES ADMINISTERING ENVIRONMENTAL IMPACT ASSESSMENT PROCEDURES IN CANADA EACH ESTABLISH A SMALL COMMITTEE OF EXPERTS TO PROVIDE GENERAL ADVICE ON SCIENTIFIC MATTERS RELATED TO ENVIRONMENTAL ASSESSMENT.

(a) The committee should review the policies and procedures under which the organization operates, and should advise on changes required to support a more scientific approach to assessment studies.

(b) The committee should assist the agency in ranking priorities for impact assessment research needs. Such ranking could include soliciting the opinions of proponents, consultants and research scientists, reviewing major research programmes relevant to environmental assessment, and informing research agencies of the main areas of knowledge deficiencies.

(c) The committee should encourage regular, non-adversarial meetings with representatives of the agency, proponents, consultants, research scientists and resource managers. Such meetings should address the current state of affairs in environmental assessment, should attempt to resolve outstanding issues, and should recommend changes in procedures and requirements to continually refine the process.

(d) The committee should encourage the agency and other relevant organizations to co-operate in organizing and conducting impact assessment training activities, including technical workshops and short courses.

(e) The committee should advise the agency on initiatives to be taken in developing in depth studies on several major problem areas in impact assessment including socioeconomic aspects, the cumulative effects of several projects in one area, regional environmental assessment, risk analysis, impact prediction and mitigation, and others. Such research

efforts should involve broad based support and participation.

(f) The committee should advise the agency on initiatives to promote information transfer and dissemination. Initiatives of particular utility to scientific practice within impact assessment include a central storage and retrieval system for all environmental assessment reports and documents prepared under the agency's procedures, an up-to-date annotated bibliography of relevant research, and case studies of impact assessments which may serve as model approaches for certain scientific aspects of environmental assessment.

Recommendation 3 — Monitoring as Part of the Assessment Process

In spite of the widely recognized importance of monitoring in environmental assessment, the assessment processes as administered in Canada generally are terminated in a formal sense after impact statements have been reviewed and project decisions are made. The Requirements for Organizing and Conducting Ecological Impact Studies include a requirement for the monitoring of project effects. While the successful implementation of this requirement (and the others) depends on its acceptance by the assessment community, it must also be acknowledged by fundamental changes in assessment procedures. The following recommendation recognizes the special procedural attention needed to translate the concept of monitoring into application.

IT IS RECOMMENDED THAT ENVIRONMENTAL IMPACT ASSESSMENT AGENCIES UNDERTAKE WHATEVER PROCEDURAL CHANGES ARE NECESSARY TO HAVE MONITORING FORMALLY RECOGNIZED AS AN INTEGRAL COMPONENT OF THE ASSESSMENT PROCESS.

(a) Guidelines or terms of reference should place emphasis on monitoring of effects as an integral part of the design of impact studies.

(b) Environmental impact statements should provide as much rationale and technical detail for monitoring studies as for pre-project studies.

(c) Agencies should clearly establish for each environmental impact assessment the responsibilities of government agencies and proponents for conducting and reviewing monitoring programmes.

Recommendation 4 — Professional Involvement in Environmental Assessment

There has been a widespread conviction within the scientific community in Canada that environmental assessment studies are largely pseudo-scientific and are to be avoided. However, the scientific basis for impact assessment is improving, and the general adoption of the Requirements for Organizing and Conducting Ecological Impact Studies will see a substantial upgrading of the scientific quality of assessment studies. As the practice of environmental assessment improves, the involvement of research scientists and natural resource experts should be fostered in every way possible.

IT IS RECOMMENDED THAT ORGANIZATIONS AND INSTITUTIONS WHICH EMPLOY RESEARCH SCIENTISTS AND NATURAL RESOURCE EXPERTS ACTIVELY ENCOURAGE THEIR INVOLVEMENT IN ENVIRONMENTAL IMPACT ASSESSMENT.

(a) The organizations and institutions should stress the importance of cooperative research and study programmes as supportive activities for impact assessment.

(b) The contributions of research scientists and experts to environmental assessment should be recognized in performance appraisals and career advancements.

(c) Increased opportunities should be provided for employees to engage in short-term transfers of work or leaves of absence related to environmental impact assessment.

Appendices

APPENDIX A

WORKSHOP PARTICIPANTS

Halifax Workshop

S. Conover	MacLaren Plansearch Limited, Dartmouth
R. Côté[1]	Environment Canada, Dartmouth
A. Ducharme	Dept. Fisheries and Oceans, Halifax
D. Gordon	Dept. Fisheries and Oceans, Dartmouth
H. Hall	Environment Canada, Dartmouth
H. Hirvonen	Environment Canada, Dartmouth
D. Kelly	Environment Canada, Dartmouth
L. MacLeod	N. S. Dept. Fisheries, Halifax
D. Nettleship	Environment Canada, Dartmouth
J. G. Ogden III	Dalhousie University, Halifax
D. O'Neill	Environment Canada, Bedford
F. Payne	N. S. Dept. Lands and Forests, Kentville
C. Ross	Mobil Oil Limited, Halifax
M. Westaway[2]	British Petroleum, London

Vancouver Workshop

A. Cornford	Dept. Fisheries and Oceans, Sidney
K. Hall	University of British Columbia, Vancouver
C. S. Holling[2]	University of British Columbia, Vancouver
R. Jakimchuk	Renewable Resources Cons. Services, Sidney
C. Johansen	Swan Wooster Eng. Co. Ltd., Vancouver
G. Kaiser	Environment Canada, Delta
R. MacDonald	Dept. Fisheries and Oceans, Sidney
D. Marshall[1]	Federal Environ. Assess. Review Office, Vancouver
A. Milne	Dome Petroleum, Calgary
E. Owens	Woodward-Clyde Consultants, Victoria
E. Peterson	Western Ecological Services (B. C.) Ltd., Sidney
W. Rees	University of British Columbia, Vancouver
W. Speller	Petro-Canada, Calgary
A. Tamburi	Western Canada Hydraulic Labs. Ltd., Port Coquitlam
M. Waldichuk	Dept. Fisheries and Oceans, Vancouver
J. Wiebe	Environment Canada, Vancouver

Edmonton Workshop

T. Barry	Environment Canada, Edmonton
N. Brandson	Manitoba Dept. Environment, Winnipeg
W. Fuller	University of Alberta, Edmonton
S. Hirst	B. C. Hydro, Vancouver
R. Hofer	Environment Canada, Regina
R. Livingston	N. W. T. Dept. Renewable Resources, Yellowknife
E. MacDonald	B. C. Hydro, Vancouver
R. Morrison	Dept. Indian Affairs and Northern Dev., Ottawa
G. Rempel	Esso Resources Canada Ltd., Calgary
R. Stone	Alberta Environment, Edmonton
C. Surrendi[1]	Hardy Associates (1978) Ltd., Edmonton
J. Truett[2]	LGL Limited, Grand Junction, Colorado
J. Verschuren	University of Alberta, Edmonton
G. Walder	Aquatic Environments Ltd., Calgary
S. Zoltai	Environment Canada, Edmonton

Toronto Workshop

J. Carreiro	Environment Canada, Ottawa
D. Heath	Ontario Hydro, Toronto
D. Hoffman	University of Waterloo, Waterloo
G. Hughes	Environment Ontario, Toronto
S. Llewellyn	Environment Canada, Toronto
P. Peach	Brock University, St. Catharines
F. Pollett[2]	Environment Canada, St. John's
R. Ruggles	Ontario Hydro, Toronto
B. Savan	Environment Ontario, Toronto
K. Schiefer	Beak Consultants Limited, Mississauga
J. Sparling	Environmental Applications Group Ltd., Toronto
D. Thomson	LGL Limited, Toronto
B. Thorpe	Environment Ontario, Toronto
D. Young[1]	Environment Ontario, Toronto

Brandon Workshop

L. Barnthouse[2]	Oak Ridge National Laboratory, Tennessee
P. Boothroyd	Environment Canada, Winnipeg
N. Brandson[1]	Manitoba Dept. Environment, Winnipeg
D. Brown	Manitoba Dept. Environment, Winnipeg
L. K. Caldwell	Indiana University, Bloomington
R. Clarke	Dept. Fisheries and Oceans, Winnipeg
A. Derksen	Manitoba Dept. Natural Resources, Winnipeg
P. Duffy	Federal Environ. Assess. Review Office, Hull
W. Fraser	Hudson Bay Mining and Smelting Co. Ltd., Flin Flon
H. Gavin	Environment Canada, Winnipeg
G. Mills	Manitoba Dept. Agriculture, Winnipeg
R. Riewe	University of Manitoba, Winnipeg
R. Rounds	Brandon University, Brandon
K. Simmons	University of Manitoba, Winnipeg
M. Staley	E. S. S. A. Ltd., Vancouver
G. Teleki	Ontario Ministry Municipal Aff. and Housing, Toronto
R. Thomasson	Manitoba Dept. Natural Resources, Winnipeg
D. Wotton	Manitoba Dept. Environment, Winnipeg

Saskatoon Workshop

A. G. Appleby	Dept. of Northern Saskatchewan, Prince Albert
F. M. Atton	Sask. Dept. Tourism and Ren. Resources, Saskatoon
D. Botting	Executive Council Sask. Government, Regina
W. Clifton	Clifton Associates Ltd., Saskatoon
W. E. Cooper[2]	Michigan State Univ., East Lansing
A. Dzubin	Environment Canada, Saskatoon
E. Jonescu	University of Regina, Regina
D. Lush	Beak Consultants Limited, Mississauga
G. Mutch[1]	Saskatchewan Environment, Regina
R. Neumeyer	Environment Canada, Regina

W. Pepper	Sask. Dept. Tourism and Ren. Resources, Saskatoon
Reid	Potash Corp. of Saskatchewan, Saskatoon
Tones	Saskatchewan Research Council, Saskatoon
E. Walker	Saskatchewan Environment, Regina
Zytaruk	Saskmont Engineering, Saskatoon

Andrews Workshop

Ayer	N. B. Dept. Environment, Fredericton
L. Baskerville	N. B. Dept. Natural Resources, Fredericton
Boer	N. B. Dept. Natural Resources, Fredericton
Cardy	N. B. Dept. Environment, Fredericton
Carter	Martec Limited, Halifax
B. Cowell[2]	British Petroleum, London
Henderson	N. B. Environmental Council, Fredericton
Keppie	University of New Brunswick, Fredericton
Langmaid	St. Andrews
MacKay	Marine Research Associates, St. Andrews
Monti[1]	N. B. Dept. Environment, Fredericton
Scarratt	Dept. Fisheries and Oceans, St. Andrews
Seibert	Dept. Fisheries and Oceans, Halifax

ntreal Workshop

.. Belair	Environnement Canada, Ste.-Foy
R. Boudreault	Ministère de l'Environnement, Ste.-Foy
Dumouchel	Eco-recherches Inc., Pointe Claire
Jacobs[1]	Université de Montréal, Montréal
Lafargue	Université de Montréal, Montréal
Lagace	Ministère du Loisir, Chasse et Pêche, Orsaineville
Lehoux	Environnement Canada, Ste.-Foy
Marsan	A. Marsan et Associés, Inc., Montréal
Penn	Grand Council of the Crees, Montreal
Rosenberg[2]	Dept. Fisheries and Oceans, Winnipeg
. Sasseville	Université de Québec, Ste.-Foy

John's Workshop

Barnes[1]	Nfld. Dept. Environment, St. John's
F. Bennett	Memorial Univ. of Newfoundland, St. John's
E. Birchard	Imperial Oil Limited, Toronto
I. Borthwick	Woodward-Clyde Consultants, St. John's
R. Buchanan	LGL Limited, St. John's
B. W. Bursey	Nfld. and Labrador Hydro, St. John's
L. Davidson	Newfoundland Seaconsult Ltd, St. John's
J. A. Hancock	Nfld. Dept. Culture, Recreation and Youth, St. John's
G. Hunter	Hunter and Associates, Mississauga
B. Johnson	Environment Canada, Sackville (N. B.)
C. Noll	Nfld. Petroleum Directorate, St. John's
T. Northcott	Northland Associates Limited, St. John's
J. Osborne	Environment Canada, St. John's
G. Payne	Dept. Fisheries and Oceans, St. John's
L. Rowe	Mobil Oil Limited, St. John's
R. J. Wiseman	Dept. Fisheries and Oceans, St. John's

Mont Ste. Marie Workshop

R. Baker	Environment Canada, Hull
H. Boyd	Environment Canada, Hull
J. Donihee	N. W. T. Dept. Renewable Resources, Yellowknife
P. Duffy[1]	Federal Environ. Assess. Review Office, Hull
J. England	University of Alberta, Edmonton
D. Gamble	Canadian Arctic Resources Committee, Ottawa
G. Glazier	Petro-Canada, Calgary
A. Heginbottom	Dept. Energy, Mines and Resources, Ottawa
M. Kingsley	Environment Canada, Edmonton
A. Knox	Envirocon Limited, Vancouver
P. Leblanc	Nova Scotia Power Corp., Halifax
P. McCart	Aquatic Environments Ltd., Calgary
F. McFarland	Dept. Indian Affairs and Northern Dev., Ottawa
B. Moore	Environment Canada, Edmonton
W. Nielson	Gulf Canada Resources Inc., Calgary
J. Percy	Dept. Fisheries and Oceans, St. Anne de Bellevue
D. Schell[2]	University of Alaska, Fairbanks
B. Smiley	Dept. Fisheries and Oceans, Sidney

[1] Workshop co-ordinator
[2] External expert

APPENDIX B

WORKSHOP PARTICIPATION BY AFFILIATION

Workshop	Federal	Provincial	University	Consultant	Industry	Miscellaneous	Total
Halifax	8	2	1	1	2	0	14
Vancouver	6	0	3	5	2	0	16
Edmonton	5	2	2	3	3	0	15
Toronto	3	4	2	3	2	0	14
Brandon	5	7	4	1	1	0	18
Saskatoon	2	6	2	4	1	0	15
St. Andrews	2	5	1	4	1	0	13
Montreal	3	2	3	2	0	1	11
St. John's	4	3	1	5	3	0	16
Mont Ste. Marie	9	1	2	2	3	1	18
TOTAL	47	32	21	30	18	2	150
PERCENTAGE	31.3	21.3	14.0	20.0	12.0	1.4	100

APPENDIX C

RESULTS OF TWO CASE STUDIES

BACKGROUND AND METHODS

One of the early objectives set for the research project was to determine the extent to which the possibilities we identified for improving the ecological substance of environmental assessment could be applied in a current time frame. By this means, we hoped to ensure, as much as possible, that the results of the project would not be relegated to the realm of the academic and theoretical. Two impact assessments recently completed in Canada were used to identify constraints against, and opportunities for, the application of ecological and more general scientific concepts and techniques.

The assessments were very different in many respects, a fact which strengthens common messages arising from both. One assessment dealt with impacts of extremely low probability of occurrence, the other with impacts of very high probability of occurrence. One involved primarily a marine system, the other terrestrial and aquatic systems. One was undertaken according to the federal assessment policy, the other according to a provincial, legislated assessment process.

Both impact assessments were reviewed early in 1982 and involved two sources of information. First and foremost were interviews with proponents, consultants and government researchers who played significant roles in either of the two assessments (Table C-1). Background information and a list of questions were circulated to each person prior to the consultation. The questions did not constitute a formal questionnaire; they were designed to reflect the important subject areas of our research and to give advance notice to the interviewees of the range of topics under consideration.

The second source of information included the written documentation for each impact assessment. In each case, the documentation consisted of an environmental impact statement, an addendum to that statement, and numerous reports dealing with the results of individual studies.

Table C-1

Persons Interviewed as Part of the Case Studies

Assessment for the South Davis Strait Project

Mr. Evan Birchard	Imperial Oil Ltd.,Toronto
Dr. Shirley Conover	MacLaren Plansearch Ltd., Dartmouth
Mr. George Greene	Environmental Sciences Ltd., Calgary (formerly:Imperial Oil Ltd., Calgary)
Mr. Robert Webb	R.Webb Environmental Services Ltd., Calgary

Assessment for the Upper Salmon Hydroelectric Project

Dr. David Barnes	Nfld. Dept. Environment, St.John's
Mr. Bruce Bursey	Nfld. Dept. Development, St.John's (formerly:Nfld. and Labrador Hydro)
Mr. Edward Hill	Nfld. and Labrador Hydro, St.John's (formerly:Northland Associates Ltd., St.John's)
Mr. David Kiell	Nfld. and Labrador Hydro, St.John's
Mr. Shane Mahoney	Nfld. Wildlife Division, St.John's
Dr. Gregory Pope	Beak Consultants Ltd., St.John's
Mr. Norman Williams	Nfld. Dept. Environment, St.John's

-F-SHORE PETROLEUM EXPLORATION ROJECT

ickground

'he proposal for which this environmental impact assessnt (EIA) was undertaken involved a two to three year gramme of exploratory hydrocarbon drilling in the Davis ait, located in northeastern Canada. While the propoits included three companies (Imperial Oil Limited, Aquie Company of Canada Limited, and Canada-Cities Ser- Limited), a joint proposal was submitted and a iperative assessment undertaken. This impact assesst was called for by the then federal Department of an and Northern Affairs, (DINA), and was conducted ler the terms of the federal Environmental Assessment Review Process (EARP). DINA specified that a regional roach be taken to the environmental assessment; in er words, rather than focus on specific well sites, the essment was to incorporate a broad area of the Davis iit stretching from just north of Labrador to Cape Dyer Baffin Island.

riefly, the companies proposed to use dynamically posied drill ships during the open-water season to carry out r exploration programme. They submitted their proposal DINA in the summer of 1976, with the intent to gain roval for drilling in the summer of 1979. The proponents ertook field studies during 1976 and 1977 and submit- the EIS (Imperial Oil Ltd. *et al*., 1978) in January of 8. Public review hearings took place in September of year at which time the proponents brought forth addial information from studies undertaken during the 1978 season. The Environmental Assessment Panel, establd by the Federal Environmental Assessment Review e (FEARO) to conduct the public review of the assesst, tabled its report to the Minister of the Environment in ember, 1978. The proponents then published a supplet to the EIS early in the following year (Imperial Oil Ltd. ., 1979). Drilling was approved and began, as planned, e summer of 1979.

ie EIS focussed on potential impacts that might occur ie event of an uncontrolled oil well blowout. Other icts, resulting from routine drilling operations and rig cing, were considered of little importance when comd with the potential threat of an oil spill to the biota and irce users of the region. The EIS requested approval d on a very low probability of a well blowout and the mmendation of the assessment Panel (i.e., that the ct be allowed to proceed with certain conditions hed) reflected this recognition of low probability. iuse of this peculiar aspect, the impact assessment l only identify and assess *potential* impacts, most of n would not occur unless there was a well blowout.

ectives

e objectives for this impact assessment, as stated in ormal guidelines (FEARO, 1978) and in the EIS rial Oil Ltd. *et al*., 1978), were somewhat conflicting. The government felt the objective should be, "to determine those areas where, from an environmental point of view: (i) drilling can proceed and under what conditions, (ii) drilling cannot proceed, and (iii) insufficient data exists on which to base a decision" (FEARO, 1978). On the other hand, the proponents stated that they had, "conducted environmental studies to define the possible impact that drilling activities may have upon this offshore region and the adjacent Baffin Island area" (Imperial Oil Ltd. *et al*., 1978). There are two main reasons why the proponents would not have adopted the objective outlined in the guidelines. First, each of the three proponents had specific acreage within the whole study area for which approval was being sought. In preparing a joint regional assessment, it would have been unacceptable for the EIS to conclude that drilling could proceed within the holdings of one proponent and not in the holdings of another. Secondly, proponents in general obviously have the unwritten objective of obtaining project approval and are reluctant to point out areas where lack of knowledge could delay that approval.

It is clear that neither the objectives of the proponent nor the objectives in the guidelines, as written, provided much direction to the assessment at an operational level. Such broad objectives must be translated into more detailed statements that practitioners can use to derive detailed plans of study and which reviewers can use to gauge the success of the assessment.

Interviewees indicated that no specific objectives were struck at the beginning of this assessment. They suggested that only general objectives were possible for such a broad, regional impact assessment in a frontier area. Indeed, it was apparent that the proponents had a very specific unwritten objective and that was to obtain *regional* clearance for the commencement of exploratory drilling by 1979. This objective was met!

Guidelines

An initial set of guidelines was issued to the proponents by DINA in July, 1976 (FEARO, 1978). The formal guidelines are dated January, 1978, the same date as appears on the EIS itself. However, it was noted during the interviews that the proponents and consultants were not operating in a complete directional vacuum; they had access to a draft set of the formal guidelines a short time before the EIS was published.

A careful review of the guidelines (presented as an appendix in FEARO, 1978) revealed that they suffered from the ills common to most other Canadian impact assessments reviewed; namely: (i) they attempted to be all-encompassing, (ii) they prescribed a sectorial, descriptive approach, and (iii) they failed to recognize the operational implications of many of the activities required.

For example, consider the request to identify and describe *all* environmental impacts likely to arise as a result of the project. Both the writings (e.g., Truett, 1978; Larminie, 1980b) and our workshops suggest that this is an unrealistic objective. As another example, the guidelines

called for a discussion of the capacity of biological systems to assimilate pollutants which may be emitted by the project. While a good knowledge of assimilative capacity would undoubtedly improve our ability to predict the effects of a marine oil spill, the acquisition of such knowledge, given the current state of our understanding, was beyond the scope of such an assessment.

The interviewees generally reflected a neutral opinion of the guidelines. One person was quick to point out that the impact assessment included much valuable information that was not called for in the guidelines. This set of guidelines was only considered useful as a late reference for topics which previously may have been overlooked and as a guide for organizing the writing of the EIS.

Scoping and Study Planning

The nature and importance of scoping have been described earlier in this report. The documentation for this impact assessment did not refer to any formal attempt to scope the issues. However, the interviews revealed that an informal attempt was made to identify the more important concerns through the use of an interaction matrix. Simply put, this is a large table, with project activities and events listed along one dimension and specific environmental components along the other. If an interaction is expected between a particular project activity or event and a specific environmental component (e.g., a species), then the appropriate box in the matrix is marked. Once the matrix is complete, it becomes clear that certain project activities and environmental components are severely implicated. The most obvious result of this exercise was the identification of an oil well blowout as the single, most important project-related event from an impact assessment perspective.

When viewed in its entirety (i.e., inclusive of the 1978 field programme), it is apparent that a concerted effort was made to use the results of early investigations in focussing the later studies. The proponents and consultants felt that impact assessment studies for projects in frontier areas such as the Canadian Arctic, must begin at the reconnaissance level; not enough is known beforehand to provide an adequate basis for scoping. According to one interviewee, initial studies had to reflect the need to know, "what is where, when." While we argue that specific ecological questions should be asked as early as possible to provide direction to the field studies, the interviewees felt that such questions would not have been reasonable at the beginning without a firm basis in biological studies. As these studies progressed, the proponents and consultants, with the advice of academic and government scientists, were able to formulate specific ecological questions and to design studies to answer them.

On the other hand, one person admitted that if the practice of impact assessment in general had developed to the stage, at the time this assessment was being planned, where everyone expected only specific important questions to be raised and studied, the proponents and consultants certainly could have done so. This alludes to a recognition that not all of the early surveys were grounded in a 'need to know' rationale.

Impact Significance

Earlier in the report we discussed the importance of clearly establishing a context for judging the significance of environmental impacts. This environmental assessment was notable in this regard. While the framework was devised and applied only *after* the 1976 and 1977 field programme, it presented a clear indication of major, moderate, and minor impacts (Table C-2). These designations were used to qualify all impacts predicted in the assessment.

Table C-2
Criteria Used to Rate Impacts in the Environmental Impact Assessment of Exploratory Hydrocarbon Drilling in the Davis Strait Region

(from Imperial Oil Limited *et al.*, 1978).

MAJOR IMPACT —	A *Major Impact* affects an entire population or species in sufficient magnitude to cause a decline in abundance and/or change in distribution beyond which natural recruitment (reproduction, immigration from unaffected areas) would *not* return that population or species, or any population or species or dependant upon it, to its former level within several generations. A major impact may also affect a subsistence or commercial resource use to the degree that the well being of the user is affected over a long term.
MODERATE IMPACT —	A *Moderate Impact* affects a portion of a population and may bring about a change in abundance and/or distribution over one or more generations, but does not threaten the integrity of that population or any population dependent upon it. A short-term effect upon the well-being of resource users may also constitute a moderate impact.
MINOR IMPACT —	A *Minor Impact* affects a specific group of localized individuals within a population over a short time period (one generation or less), but does not affect other tropic levels or the population itself.

In comparison with our context for impact significance as discussed earlier, these criteria do not include any element of statistical significance. They do, however, reflect considerable attention to ecological significance and, to a lesser extent, social importance.

While this framework allowed all parties to have a common understanding of the basis for assigning a degree of

significance to predicted impacts, it failed to make the link between impact significance and project decision-making. However, it was stated that the intention of the study team was to remain objective throughout the analysis and to interpret the potential impacts no further than ecological principles would allow. It was felt that the task of evaluating the environmental risks in the context of project decision-making should have been undertaken by the appropriate government agencies.

Boundaries

The setting of time and space boundaries has generally been neglected in environmental assessment in Canada. While the workshops generated considerable discussion on this topic, our review of impact statements revealed little evidence of the rationale behind the setting of boundaries. These case studies were instrumental in showing that considerably more attention is given to boundaries during assessments than is traditionally reflected in the assessment documentation. As is customary, spatial bounding in this impact assessment began with requirements in government guidelines and the spatial scale of the project. Regarding the former, DINA directed that the assessment should be regional, not site-specific in scope. As the Davis Strait is aligned roughly in a north-south configuration, the western and eastern shores (Baffin Island and Greenland, respectively) provided obvious natural boundaries. The northern and southern boundaries were initially determined on the basis of the combined exploration acreage held by the proponents.

During the course of the assessment, the initial boundaries were expanded somewhat on the basis of expected southward (and possible southwestward and westward) movement of a potential oil slick. The boundaries then included the biotically active and important resource areas of Hudson Strait, Ungava Bay, and the Labrador coast. The simulation modelling of oil slick trajectories, plus the influence of real or perceived concerns for important biota, were the main factors which extended the boundaries beyond the initial limits established by the project.

Ecological factors were more evident in the temporal aspects of the impact prediction. The categories for impact significance were based partly on the time scale within which a population would be able to recover to pre-impact conditions. As stated, a major impact affects a species over a period of several generations, a moderate impact over one or a few generations, and a minor impact over less than a generation. Obviously, the time boundaries vary with each species, since generation times may range from a few years to several decades for species in higher trophic levels. It was admitted in the EIS that population or community recovery times are not generally well known; as a result, it would have been impossible to specify years before full recovery. It was apparently considered adequate to group impacts into significance categories based on a general, rather than on a specific appraisal of time. While the exercise of setting boundaries was operationally useful during the prediction phase of the assessment, the framework was developed after the 1976-77 field seasons and thus provided no direction in designing the pre-EIS scientific studies.

Modelling

Apart from the interaction matrix described above, and a preliminary, qualitative food web model, no attempt appears to have been made to construct a conceptual model of the natural environment of the Davis Strait. Interviewees suggested that the limited knowledge of this environment precluded the construction of a conceptual ecological model and that an adequate assessment for this environment could be undertaken without an explicit modelling attempt.

The qualitative food web model, constructed late in the assessment exercise, was based on published information and on limited, gut content analyses. The construction of this model, although quite rudimentary, was considered a valuable aid during the impact prediction phase of the assessment.

As noted earlier, computer simulation modelling of oil slick trajectories is common practice in impact assessments of offshore petroleum activities. In this study, some thousand simulations were run for potential slicks from six representative spill sites. This trajectory modelling proved to be a necessary prerequisite for predicting biotic impacts resulting from an oil well blowout. While the review of the federal Department of Fisheries and Environment criticized the modelling effort for having used inadequate input data for winds, tides and currents (Department of Fisheries and Environment, 1978), the proponents claimed to have adequately explored 'worst case scenarios' in their slick modelling, and the judgement of the Panel reflected a satisfactory modelling exercise.

Population vs Community vs Ecosystem

The question of which level of the ecological hierarchy to focus on for impact studies and prediction was discussed at length in Part II. Initial ecological studies for this impact assessment, as mentioned previously, were designed primarily to answer the three-fold question, "What was where, when?". This approach was considered necessary owing to the general lack of a systematic understanding of the biota and resources of the area. What this amounted to was a focus on the abundance and distribution of species populations, thus providing the description of the biotic environment as requested by the guidelines.

The emphasis on the population level has some support. The question of "What was where, when?" is certainly a valid one for areas that are relatively unknown. However, it is not unreasonable to assume that some inventories could have been foregone since it could have been predetermined that the results would be of little use in predicting impacts on important elements of the system. As well, until that time (and even now), proponents were expected by

regulatory agencies to adopt this inventory approach at the population level.

Some studies were undertaken that were directed more or less at the community level of organization. These included plankton studies, benthos studies and the food web model based on gut content analyses. Responses from the interviewees indicated that the results of these studies contributed substantially towards the prediction of impacts. For example, the phytoplankton studies helped point out (i) the high degree of spatial variability in the spring bloom and (ii) the importance of that bloom in supporting high levels of biotic productivity for the remainder of the year. Also, the food web study provided qualitative information on important connections in the marine trophic structure.

On the whole, the population focus adopted in this environmental assessment appears to have been appropriate. Not only did the major environmental concerns revolve around important species, but the most serious mode of impact, that is, direct oiling, would lead one to examine first the response of the populations affected.

Baseline Studies

We have referred to the term baseline as a statistically adequate description of the temporal and spatial variability of a variable of interest. The establishment of such baselines was not rigorously pursued in a broad sense in this impact assessment, although the proponents designed the studies "to provide a regional and seasonal description of the distribution and abundance of important elements of the marine biota" (Imperial Oil Ltd. *et al.*, 1978).

The results of such studies apparently sufficed to allow semi-quantitative predictions of impact to be made. However, it is not evident that these studies could provide adequate referencing for a monitoring programme in the event of a well blowout. One interviewee argued that proponents should not be expected to shoulder the burden for undertaking such detailed baseline studies on species and resources of concern; this task should be undertaken largely by government agencies that have the mandate of managing those species and resources.

While the establishment of quantitative baselines for this assessment would have added substantially to the monetary costs involved, lack of time can hardly be considered an operational constraint in this case. Four field seasons were available from the beginning of the assessment, up to and including the first drilling season. As well, three field seasons have passed since that first drilling year. Thus, a total of six years of baseline information could theoretically be available at this time, a considerable amount for providing a reasonable tracking of important variables prior to potential future well blowouts. In conclusion, it appears that a lack of motivation and a lack of requirement have resulted in the absence of a longer-term, quantitative baseline.

Hypotheses and Experiments

Rigorous hypothesis testing through experimentation was not pursued in this environmental assessment. One person interviewed suggested that a substantial amount of implicit informal hypothesis testing did occur. For example, results of early studies led the investigators to suspect the ice edge as a very important habitat for a host of marine species at various trophic levels. Studies were subsequently undertaken to confirm this and to elucidate the relationships.

Limited experimentation in the laboratory was carried out in support of this assessment. Specifically, toxicity trials were undertaken to examine the effects of petroleum on rates of glutamate utilization in bacteria. Physical laboratory experiments involved studies on the dynamics of oil in moving pack ice.

In general, widespread use of experiments to test hypotheses was considered (i) impossible due to the lack of a basic understanding of the Davis Strait ecosystem and (ii) unnecessary in order to predict the effects of an oil well blowout on the biotic resources of the region.

Ecological Frameworks for Prediction

We have emphasized the importance of referring to recognized and known time-sequence concepts for the prediction of biotic impacts. Such ecological concepts can be found for any level of the ecological hierarchy. As mentioned previously, the focus of concern in this assessment was on the long-term viability of certain species populations. Consequently, a knowledge of a species' response to contact with oil would be required to determine direct impacts and some understanding of a species' trophic dependencies would help in tracing second-order impacts. This approach precluded the need to establish and use broad community-level or ecosystem-level predictive frameworks. Some of these broader frameworks, such as energy flow and nutrient cycling, were investigated and discussed for a very basic level of understanding of the dynamics of the Davis Strait ecosystem but were not refined to the point where they were of use in predicting specific population changes.

Prediction

The basis for impact predictions included: (i) the results of two seasons of field surveys in the South Davis Strait region, (ii) a knowledge of the effects of oil on various species, as reported in the literature, (iii) the oil slick trajectory modelling, and (iv) professional judgement. The actual technique used involved the overlaying of diagrams of simulated oil slicks on maps of the distribution of biota in various seasons.

The predicted impacts were quantitative in the sense that they were divided into groups based on considerations of magnitude, extent and duration of effect. Probability of impact was addressed only in the context of the low proba-

ity of an oil well blowout (i.e., impacts were predicted suming the occurrence of a worst-case blowout). As the obability of such a blowout was claimed by the proponts to be very low, the overriding conclusion of the sessment was that no significant adverse impacts were ely to accrue from the proposed project.

The predictions can be considered to be cast in a semiantitative form. For example, as indicated through the mework established for impact significance, a major pact on polar bears occupying ice habitat in late winter olies that the entire regional population may decline or ay change in distribution to an extent beyond which the mer population status would not be achieved for several nerations. Such semi-quantitative forms are much more nenable to post-impact testing than are vague, qualitative itements. Nevertheless, this does not imply that the pre:tions are fully testable, since testability depends on other :tors such as adequate, pre-impact control data, the :hnical ability to measure changes of the magnitude pre:ted and actual occurrence of the impact. Indeed, the :tability of the predictions made in this assessment is estionable on the grounds of an absence of adequate seline descriptions of natural variation.

The proponents and consultants adopted a 'worst-case' proach to making predictions in the absence of sufficient ormation or insight or both. The documentation emphaed that, in such cases, impacts were placed in a category of higher severity than what initially may have been ought appropriate. All cases where this occurred were ted in an oil blowout impact matrix (Imperial Oil Ltd. *et* 1978). Using the example above, the impact of a well wout on polar bears occupying ice in late winter was inily labelled a moderate impact but was recast as a major pact in light of insufficient data. There was undoubtedly me comfort underlying this strategy; the EIS dismissed risk posed by the project to the species of concern on basis of the very low probability of impact occurrence.

onitoring

The EIS called for environmental monitoring to be under:en, in the event of a major release of oil, to determine fate of the oil and its environmental effects. It was ted that the monitoring strategies and techniques as :ailed by Cox and others (1980) would be followed. This nual summarized the proceedings of a workshop on oil ll studies and the main conclusion was as follows:

'The workshop participants strongly endorse the con:ept of a few comprehensive, well-planned, statistically valid studies of oil spillages rather than many inconclusive studies which are the current norm. Oil spill impact analyses require highly sophisticated, expensive techniques which must be performed with sufficient replicaion to provide data amenable to rigorous statistical esting.''

They also emphasized the need for time controls in oil l impact studies, that is, an indication of the range of ural variability, in time and space, of variables that will be measured during and after an oil spill. While the proponents supported this concept, there was little indication that such rigorous 'baselines' had been established or were being undertaken concurrent with drilling activities. (An exception was the intensive monitoring programme on seabird distribution and abundance. This study began in 1978 but was terminated after 1979, reportedly because of a significant change of personnel within a government department). The EIS suggested that such studies would entail a cooperative effort between industry and government. In the opinion of one person interviewed, the bulk of the responsibility for these studies should lie with government, especially for species and resources for which various agencies have the mandate of management. Regardless of who should carry out such studies, their absence from this assessment seriously jeopardizes the interpretation of the results of any impact monitoring programme.

Mitigation and Contingency

The impact assessment studies provided the basis for the oil spill contingency plan for this project. The detailed contingency manuals were based primarily on resource maps which identified high priority areas and species for protection. The manuals also outlined the measures most appropriate in undertaking such protection.

As well as helping to specify appropriate mitigation and countermeasures equipment, the assessment studies also were influential in choosing a site for base camp operations and in improving other aspects of the rig servicing programme. Concerning the actual drilling procedures, equipment and locations, these were determined largely by the engineering possibilities for the project and by the probabilities of success in finding a hydrocarbon deposit within the exploration acreages.

HYDROELECTRIC DEVELOPMENT

Background

Early in 1975, Newfoundland and Labrador Hydro (Hydro) informed the Newfoundland Department of Consumer Affairs and Environment (DCAE) of its plans to examine four hydroelectric developments (including the Upper Salmon Hydroelectric Development) as generation options. A comparative preliminary environmental impact assessment of these proposed projects was undertaken and completed in 1976 (Airphoto Analysis Associates Consultants Limited/Beak Consultants Limited, 1976). This initial work concluded with recommendations for an array of more detailed studies in support of a full-scale impact assessment for the Upper Salmon project. Hydro initiated a number of these studies in 1978, and tabled an EIS for the project early in 1980 (Newfoundland and Labrador Hydro, 1980a). Approval in principle by this time already had been given for the project, but the approval was contingent upon the findings of certain studies and upon the continuation of certain other investigations.

Subsequent to the submission of the EIS, Hydro was required to prepare an environmental information report (Newfoundland and Labrador Hydro, 1981a) to address some of the deficiencies of the assessment; namely, to provide greater detail on the monitoring, research and mitigation of environmental impacts related to the project. Construction of the project has proceeded generally as expected, and operation is to commence late in 1982. Environmental studies related to the project are still being undertaken and will be described later.

This impact assessment was important for the Newfoundland environmental assessment community for a number of reasons. It was one of the first assessments to be administered under the new legislated procedures for impact assessment adopted by the Newfoundland Department of Environment. As well, a new concept, that of the 'environmental monitor' or surveillance person, began to mature with the assessment of the Upper Salmon development. While Hydro employed its first monitor for the earlier Hinds Lake Hydroelectric Project, it became customary with this assessment for DCAE to employ a monitor, in parallel with a Hydro monitor, for each hydroelectric development. The duties of the monitors are to ensure environmentally sound construction practices and to observe project-related environmental events.

Objectives

The EIS (Newfoundland and Labrador Hydro, 1980a) clearly states that the objectives of the assessment were (i) to predict impacts of the proposed project, and (ii) to identify and propose practicable mitigation measures to reduce or eliminate undesirable effects. On the other hand, the objectives for the individual studies supporting this assessment were somewhat less precise. In some cases, it was unclear how the specific studies were to provide a meaningful contribution to the overall assessment. In this regard, a nested set of objectives would have been helpful.

Guidelines

The guidance provided to Hydro for the Upper Salmon impact assessment consisted of two elements. One consisted of a four-page outline entitled "General Guidelines for the Content of an Environmental Impact Statement." As the title suggests, these guidelines provided a generalized table of contents for an EIS, and as such, provided little substantive guidance for the design and implementation of the specific studies for the assessment. Hydro also received more specific direction from an assessment committee, comprised of individuals from various provincial and federal government agencies as well as from Memorial University of Newfoundland, and chaired by an official from DCAE. This committee, in essence, controlled the assessment; that is, it required certain studies to be undertaken and reviewed the terms of reference for studies undertaken by consultants on the proponent's behalf.

There was disagreement amongst interviewees on the value of the committee as a means of guidance. Some felt that the high degree of control the committee wielded on which studies must be undertaken and how they must be done, was rather stifling to innovative and creative thinking on the part of the proponent and the consultants. Others maintained that since environmental assessment is a government process established to provide answers to government, then government bodies have the responsibility to ensure that what is done in an assessment meets their expectations.

Scoping and Study Planning

The impact assessment for the Upper Salmon project gave the investigators the rare luxury of undertaking the assessment in stages over a relatively long period prior to the beginning of construction. The scope of the investigation and the planning for studies in the full-scale impact assessment were based largely on recommendations arising from the preliminary comparative assessment (Airphoto Analysis Associates Consultants Limited/Beak Consultants Limited, 1976). Even following the completion of the first round of studies, three years were still available before project operation (but during project construction) to conduct subsequent studies — studies designed to answer much more specific ecological questions.

The approach exemplified by this assessment borders on the ideal. Seven or eight years will have been available for scientific investigations prior to the beginning of project operation. The tiered nature of the studies provided an excellent vehicle for effective study planning. Early preliminary studies allowed a more focussed effort for later detailed field programmes.

From among a host of possible concerns, emphasis was eventually focussed on caribou (the disturbance of migration patterns and the long-term viability of local herds) and salmonids (reduced recruitment to lakes and reservoirs through loss of spawning habitat by inundation or by migration blockage). One might reflect on whether it was necessary to undertake all of the earlier studies before these concerns could be identified. In retrospect, interviewees indicated that some of the individual studies did not contribute in any substantial way to identifying or addressing major concerns in the assessment. Lessons have been learned and a reduced effort will be needed for identifying the major concerns with future hydroelectric developments in Newfoundland.

Impact Significance

No context within which to judge the significance of environmental impacts was conceived or used in this assessment. There was no indication in any of the documentation of the meanings of the words used to describe the importance of impacts. Examples of such adjectives include major and minor, significant and insignificant, and high and low. While most of those interviewed recognized the need to set impacts into perspective, and to be explicit with respect to the importance of impacts, no one indicated that

any organized effort to do so was undertaken. Indeed, it was speculated that since decisions on the need and design of specific studies were so difficult to obtain through the collaborative committee process, then arriving at a working framework for impact significance through this same approach would have been next to impossible.

It appears that the absence of a context for impact sig-nificance resulted from a combination of the following fac-tors:

(a) the lack of guidance from any source about how to construct and use such a framework;

(b) the reluctance of proponents and consultants to be definitive with respect to impact signficance;

(c) the lack of consensus on the significance of impacts on environmental attributes not strictly regulated by government; and

(d) the lack of recognition of the value of having such a framework for impact significance.

The only attempt in this assessment to place impact pre-lictions into context was described by Newfoundland and .abrador Hydro (1981a). A large table was presented in /hich each predicted impact was stated concisely and was ccompanied with the following terms:

(a) type of impact — positive or negative;

(b) severity — (provincially and locally) major, moderate and minor; and

(c) duration — short-term or long-term.

:owever, neither the table nor the text gave an indication f what was meant by any of these general terms.

3oundaries

The spatial limits of the development area were precisely 'escribed in the EIS. Study boundaries however, were not onsistently well described in the reports of supporting tudies. In one extreme case, no study boundaries whatso-ver were indicated. In another case, extensive discussion ertained to the exact definition of the area under investiga-on.

Although the EIS established the study boundaries, no ationale for their location was given. While we consider ıch a rationale to be an essential part of the study report hus allowing for critical review of this important exercise), ne interviewee suggested that most study reports did not clude the rationale for setting space boundaries because f the negotiated nature of the boundaries. As a result of ıe influence of the assessment committee over the impact ssessment, the boundaries often were established through ompromise between proposals from the proponent, the onsultants and the regulatory agencies. It was suggested ıat such compromises were not amenable to description in udy reports.

In general, spatial bounding for the studies was based first on the physical changes to result from the project and secondly on the distribution of biota to be affected. Notable examples of the latter include studies on caribou and sal-monids, both of which have short migration routes that will be interrupted by the project. In the fish investigations (Beak Consultants Limited, 1980), the physical limits of upstream and downstream movement for the two major species being studied (land-locked Atlantic salmon and brook trout) were used as boundaries for the study. The boundaries for the study on the Grey River caribou herd (Mahoney, 1980) were set to include most of the limits of the annual range for the herd.

There was little evidence of any ecological rationale in the temporal aspects of impact predictions. In fact, few predic-tions of biotic impacts were described with any more than the general qualifiers short-term and long-term. These terms may have been useful had they been defined. The interviews uncovered two reasons for the absence of more specific estimations of the duration of impacts. First, it was considered impossible to be more precise given our very limited understanding of natural phenomena, especially biotic phenomena. Second, consultants and proponents in general are often unwilling to be specific, and thus commit-ted, when qualifying predictions. Such equivocacy has sel-dom been seriously questioned in the past.

Modelling

An explicit conceptual modelling exercise was not under-taken as part of this assessment. Interviewees did not indi-cate that any attempt at such modelling would have assisted them in understanding project-environment inter-actions or in planning studies. In general, it appears that conceptual modelling is considered a tool most appropriate for addressing concerns at the ecosystem level, such as nutrient budgets or energy transfers.

The only apparent application of quantitative modelling was in the study of the hydrologic regime and the changes it would undergo with the proposed development. Some simulation modelling is being planned in studying the water flow characteristics through various alternative designs for a channel improvement downstream from the Upper Salmon powerhouse.

Quantitative modelling (simulation or otherwise) of the environmental impacts of hydroelectric projects appears to concentrate on impacts within new reservoirs (e.g., Thérien, 1981) or impacts from changed downstream physical and chemical conditions or both. In the case of the Upper Salmon Hydroelectric Development, the main impact con-cerns involved altered migration patterns of caribou and salmonids; the chemical and physical characteristics of the reservoirs were expected to undergo little change. As a result, there was little need for ecological modelling of the reservoirs.

Population vs Community vs Ecosystem

While the primary concerns in this assessment involved the integrity of faunal populations, not all of the studies undertaken were specifically focussed on this level. For example, the levels of community and ecosystem were addressed in the biophysical study (Northland Associates Limited, 1979a). Vegetation communities were mapped in this exercise, as were ecological land units based on the principles of ecological land classification (Environmental Conservation Service Task Force, 1981). The results of this study were instrumental in (i) choosing a route for the main access road and (ii) quantifying certain types of wildlife habitat that would be lost by inundation.

Other studies relied on a combination of investigations directed at the organism and population levels in order to address population level questions. The best example concerns the examination of effects on caribou (Mahoney, 1980; and E. L. Hill, pers. comm.). While part of the study involved radiotelemetric tracking of tagged individuals, another aspect was designed to observe the behavioural and migratory patterns adopted by individuals or small groups of individuals as they respond to the construction activity and presence of the project.

This impact assessment provides a good example of going beyond species distribution and abundance in study planning and design. While most of the important ecological questions pertained to the level of species populations, advantage was taken of approaching the problems at other levels that were more amenable to investigation.

Baseline Studies

Few adequate baselines, as we have described them earlier in this report, were established in this environmental assessment. Two of the better pre-project baselines established include the quantification of salmonid spawning and rearing habitat expected to be lost, and the study of migration patterns and behaviour of caribou. Most of the remaining studies were, to varying degrees, snapshot descriptions of the environment.

The interviews revealed a number of impediments to establishing adequate baselines, and also why these snapshot descriptions of the environment persist. First, many practitioners and reviewers believe that qualitative environmental descriptions have an important role to play in impact assessments. Secondly, the universal limitations of inadequate time and money were offered as reasons why blitz-style surveys predominate over directed, quantitative baselines. There is a general feeling that at least three field seasons (years) are required to allow an adequate appreciation of natural variation. Consultants often are not given this temporal luxury, being asked to complete studies in as little time as a few months. As well, studies are usually planned with a view to minimizing logistical complexity, resulting in intensive but short-term study operations. Finally, the cost of establishing firm baselines in areas accessible only by helicopter transport (e.g., the Upper Salmon area prior to completion of the access road) may exceed the financial resources available for the impact assessment.

Hypotheses and Experiments

Rigorous hypothesis testing was not undertaken in this assessment. Those interviewed suggested that this deficiency was not the result of hypothesis testing being technically impossible (although the need for more study time was mentioned), but rather the result of attitudes of various study planners and assessment committee members and their perceptions of what constitutes an adequate environmental impact assessment. Since many practitioners and assessment reviewers retain the view that impact assessment studies should be descriptive and survey oriented, there is little incentive to abandon those studies in favour of more directed studies designed to provide answers to specific questions. Indeed, one interviewee was of the opinion that a study approach dominated by hypothesis testing may result in the inadvertent omission of studying, even superficially, an element of the environment that later turns out to be an important concern.

It was also evident from the interviews that many hypotheses were being tested in a non-rigorous sense in the minds of the scientific investigators. However, such hypotheses and tests are seldom committed to the written record. It was suggested that this easily could have been done if required.

Most of the interviewees agreed that impact studies should shift from emphasis on the descriptive survey to emphasis on hypothesis-testing studies. One interviewee cautioned that special care must be exercised in formulating hypotheses to be tested during an impact assessment; specifically, the scale of the questions asked must reflect the ability to provide answers within the limits posed by the timing, financial and procedural constraints on the assessment.

The major experiments conducted for this assessment have used and are using the project itself as the source of perturbation. For example, the caribou migration and behaviour studies are based on actual construction activities and project structures as the "experimental manipulation." The stream crossing-fish migration study (Shawmont Newfoundland Ltd., 1981) has investigated fish passage at actual culvert installations in the access road.

Ecological Frameworks for Prediction

As in the case of the environmental assessment for offshore petroleum exploration discussed earlier, the impact concerns in the Upper Salmon impact assessment were at the population level, specifically with respect to caribou and salmonids. Consequently, the time-related ecological concepts used most frequently in predicting impacts on such populations were not community and ecosystem level concepts. The frameworks of importance to this assessment

involved population-habitat interactions and the importance of unimpeded migration to the viability of populations.

Habitat

Most of the studies undertaken during this assessment had some degree of focus on either fish or wildlife habitat. The biophysical study (Northlands Associates Limited, 1979a) dealt primarily with habitat loss and creation from the proposed project. The reservoir preparation study (Northlands Associates Limited, 1979b) elaborated on the changes in shoreline and littoral habitat that would occur following alternative clearing strategies for the reservoirs. A great deal of emphasis was placed on an interpretation of habitat, and its potential, in the wildlife survey (McLaren, 1979), and on the quantification of losses of salmonid spawning and rearing habitat in the aquatic studies (Beak Consultants Limited, 1980; 1981). As well, the stream crossing investigations (Shawmont Newfoundland Ltd., 1981) were partly directed at assessing salmonid habitat in the streams being examined. Finally, part of the long-term caribou study (Mahoney, 1980) has been directed at elucidating caribou preferences for various types of habitat.

The degree to which a habitat approach can be taken may in many cases be a reflection of the degree to which adequate quantification of habitat is possible. One interviewee suggested that the survey of salmonid spawning and rearing habitat was not difficult to undertake in the Upper Salmon watershed where the streams are relatively homogeneous in a spatial sense. In other situations, such as the Cat Arm watershed in northern Newfoundland in which stream morphology varies considerably, the habitat approach to fish impact studies would be much more difficult and expensive to undertake.

Migration

Perhaps even more important than habitat impacts in this assessment were the interruptions of the seasonal migration patterns of caribou and salmonids. In recognition of this, several studies were undertaken, or are currently underway, to examine and quantify these migration disruptions.

As is the case in using the habitat approach to predicting impacts on species populations, the gap between changes in migration patterns and population variables must be bridged by professional judgement. In this sense, few studies were undertaken to improve on such professional judgement, and those that were are considered somewhat inconclusive. The assessment recognized the unpredictable nature of the effect of migration changes on the viability of the caribou population and in doing so initiated a study that will attempt to document these effects for the benefit of future assessments of hydroelectric and other projects.

Prediction

One of the prime objectives for this impact assessment was to predict impacts from the proposed development (Newfoundland and Labrador Hydro, 1980a). The impact predictions were summarized in a table in Newfoundland and Labrador Hydro (1981a). Approximately one third of the predictions were quantified, and these included impacts on loss of fish and wildlife habitat, reservoir flushing rates, permanent alteration of land, destruction of forest resources and some socio-economic benefits. The unquantified predictions dealt mainly with effects of the project on biotic productivity and the presence-absence and abundance of species. In this respect, the Upper Salmon environmental assessment is similar to most other assessments of hydroelectric projects in that quantified predictions were provided only for direct physical changes.

This situation may reflect a number of underlying causes. First, it seems that physical environmental changes are relatively easy to calculate whereas most biotic impacts remain speculative and in the realm of professional judgement. The interviews suggested that quantified predictions for biotic impacts are seldom possible because of (i) a lack of understanding of causal relationships for ecological phenomena, and (ii) the high degree of chance events in natural phenomena. As well, it was apparent that some consultants and proponents are uncomfortable in committing themselves to quantified predictions. Thus, the expected direction, magnitude, extent, and duration of impacts are expressed with qualitative adjectives.

Monitoring

The term monitoring has taken on a special meaning for some members of the impact assessment community in Newfoundland; it refers to the supervision and surveillance of construction activities by an environmental officer. In this report, monitoring refers simply to measurement of environmental variables over time, often associated with studies undertaken during and after project initiation.

This environmental impact assessment is acknowledged for its commitment to extensive monitoring and research activities. As described by Newfoundland and Labrador Hydro (1981a), these studies include:

(a) a three-year stream crossing study to assess fish passage through various culvert installations;

(b) extensive water quality and quantity monitoring (some of which is routinely called for by regulatory agencies);

(c) a long-term study on the successional change of vegetation in an important local delta;

(d) a study to examine the effectiveness of water release from the West Salmon dam to preserve spawning habitat in the lower West Salmon River; and

(e) the long-term caribou migration and behaviour studies already described.

This commitment to follow-up studies is accompanied by written recognition (Newfoundland and Labrador Hydro, 1981a) of the need for monitoring to (i) check the effectiveness of mitigation measures and (ii) to improve predictive

capability. The interviews substantiated these views but they also pointed out that considerable pressure was needed from certain regulatory agencies to obtain a commitment for some of the studies. This leads to two general conclusions on why impact assessments so often lack follow-up monitoring and research programmes:

(a) proponents are generally unwilling to spend time and money on a particular environmental assessment after the EIS is submitted; and

(b) regulatory agencies often fail to take action in requiring such studies.

Mitigation and Compensation

Both the assessment reports and the interviewees stressed the importance of the mitigation of impacts. For ease of description, Newfoundland and Labrador Hydro (1981a) divided the discussion of impact mitigation into two groups — (i) measures that normally are components of sound environmental planning and construction practice and (ii) special actions and structures that a project normally would not incorporate. The former category included the site selection process for the access road and the transmission line, and special consideration for the Godaleich Pond delta in siting the powerhouse.

Mitigative measures as special actions and structures were more numerous and included:

(a) downstream channel improvements to prevent permanent flooding of the Godaleich Pond delta;

(b) preparation of the reservoir to remove barriers to caribou migration and boat passage;

(c) water release facilities to protect salmonid stream habitat in the North Salmon and West Salmon Rivers;

(d) special design of the access road to facilitate crossing by caribou;

(e) design improvements in the power canal, penstock and diversion channels to facilitate crossing by caribou; and

(f) construction restrictions (i.e., work stoppage) on account of (i) nearby caribou or (ii) archaeological finds.

Given that one of the primary objectives for the assessment was to identify mitigation measures, it is appropriate to examine whether the studies undertaken were effective in doing so. Two examples in particular demonstrate success in this regard. The purpose of the reservoir preparation study (Northland Associates Limited, 1979b) was to recommend a clearing strategy that would minimize or eliminate impacts. The aquatic investigations (Beak Consultants Limited, 1980) were instrumental, when combined with details of project design, in pointing out alternative viable mitigation techniques (especially water release for stream habitat maintenance and provision of fish passage around obstacles) for protection of the fish resources of the area.

Of particular significance are current studies examining the feasibility of substituting a fish stocking programme for the stream habitat maintenance programme. Since the ultimate objective of the latter is to maintain viable stocks of sport fish (specifically, land-locked Atlantic salmon and brook trout), in the reservoirs, then artificial stocking from a hydro-sponsored hatchery may be more cost-effective than the water release programme.

SUMMARY OF FINDINGS

Some Notable Achievements

These case studies have revealed some notable applications of a number of the concepts described earlier in this report. Along with several other examples cited earlier, they have indicated that many members of the impact assessment community in Canada have been cognizant of the ecological shortcomings of environmental impact assessment as it has developed over the past decade.

In many cases, the efforts to improve the ecological basis for environmental assessment have exceeded the explicit requirements established by administrative agencies. For example, in the Davis Strait assessment, the development and use of an ecological framework for impact significance resulted from the motivation of the proponents and consultants to upgrade the scientific integrity of the predictive analysis. In other cases, it is clear that the inputs and requirements of government agencies have contributed to sound impact assessment studies and analyses. Thus, it was recognized by Newfoundland government agencies and Hydro that impacts of the Upper Salmon Hydroelectric Project on local caribou herds could not be predicted with sufficient accuracy, and a major co-operative research programme was launched to document the effects.

Some combination of motivation and requirement also appears to account for other strengths in these assessments. Specifically, one of the most important components of the Davis Strait assessment was the preparation of detailed oil spill contingency plans. A major effort in the Upper Salmon studies was focussed on using the results to prescribe appropriate mitigation.

In summary, three factors appear to be associated with improvements in the ecological basis for environmental assessment: (i) recognition of the main problems and an appreciation of the solutions, (ii) motivation on the part of practitioners to pursue improvements, and (iii) the position of government review agencies to accept nothing less than high quality assessment work.

Constraints Against Improvement

The case studies have also shown many areas where the two assessments have fallen short of standards that might be set on the basis of a perceived ideal assessment. Through the use of personal interviews in investigating the

factors underlying these inadequacies, it often was difficult to distinguish between perceived and real constraints. As well, it has been necessary to speculate on the reasons behind many of the responses to the questions posed. At times, interviewees doubtlessly were inclined to defend specific interests or parties connected with the assessments, resulting in the inevitable shading of responses. Also, some of those interviewed had only been exposed to the findings of this research project through an early progress report (Beanlands and Duinker, 1981). Therefore, the implications of implementing some of the concepts discussed may not have been fully realized.

Nevertheless, from a combination of the explicit and implicit messages arising from the interviews, it has been possible to identify a number of factors which largely account for the character of the assessments reviewed. First, on the technical side, both assessments were faced with the task of understanding environments for which no substantial knowledge base had previously been developed. Neither the Davis Strait nor the Upper Salmon watershed had been relatively well studied prior to the assessments and consequently the study programmes were forced to begin with a substantial effort at the reconnaissance level. This was especially so for the Davis Strait assessment which, by definition of the project, encompassed a very large area of a poorly understood ocean.

It is difficult to say whether this feature of the assessments should have limited the extent to which more detailed ecological studies, possibly incorporating simulation modelling, experimentation, or specific baseline studies, were undertaken. The investigators undoubtedly would have appreciated more time and financial resources in order to improve their understanding of the potential impacts. The proponents however, had specific project schedules in mind, and seemed prepared to submit the assessment documents for review based on whatever information could be collected in the time available. In the Davis Strait assessment, the proponents claimed that further study (beyond that upon which the initial predictive analysis was based) would have served to amplify, but not significantly alter, the impact predictions.

For certain types of study, especially the establishment of baselines against which to measure project-induced perturbations, it appears that a shortage of time may not be an overriding constraint. Indeed, the fact that such a baseline has been incorporated into the caribou study of the Upper Salmon assessment is evidence that temporal limitations can, in some cases, be overcome. The key seems to be to make appropriate decisions early and then undertake the studies without delay. From a temporal perspective, opportunities for undertaking pre-impact monitoring for the Davis Strait assessment were even greater than in the case of the Upper Salmon — that is, ongoing baseline studies would continually improve the data base for variables of interest until an oil well blowout finally (if ever) occurred or until an adequate baseline fix had been achieved. But such baseline studies have not been undertaken. Perhaps because of the very low probability of such a blowout ever occurring, the possible sponsors of such studies (i.e., government or the proponents or both) have either not been motivated or not set the requirements to establish rigorous baselines.

Logistical constraints were also identified as having limited the knowledge base for predicting impacts or specifying mitigation or both. Of greatest importance in this respect is the difficulty and uncertainty in gaining access, at specified times, to the remote study areas by way of air or sea. As well, the technical requirements of undertaking certain studies would have been nearly impossible to meet. For example, had pelagic fish been implicated in case of an oil well blowout in the Davis Strait, it would have been a logistical nightmare to undertake sufficient surveys to document fish distribution and abundance. While these limitations were identified in the interview discussions, none of the interviewees indicated that the knowledge base for the predictive analyses was seriously deficient purely on account of such technical limitations.

It has become apparent that the major limitations against applying many of the concepts discussed during the interviews were not largely technical in nature. On the contrary, the more important constraints appeared related to the attitudes and perceptions of the persons involved and to the administrative and institutional forces at work. In particular, the three most pervasive factors were: (i) lack of recognition of, and agreement on, what elements comprise an ecologically adequate impact assessment, (ii) a lack of motivation, and (iii) a lack of requirement.

These constraints are particularly relevant for aspects of impact assessment to which field constraints do not directly apply; for example, in establishing a framework for impact significance, or giving rigorous attention to setting appropriate boundaries. But they are also evident in field-related concepts. In the case of the hydroelectric development, it was clear that the descriptive nature of some of the studies undertaken was determined by the perception that such studies provided the appropriate information base for the assessment. In the Davis Strait assessment, a lack of continued government requirement for certain studies appeared responsible either for their exclusion or their early termination.

Conclusions

This report has emphasized that substantial improvements can be made in the contribution of ecology to environmental assessment. It is recognized that analysis within impact assessments will always be limited by the knowledge base either already established or obtainable in the appropriate period. Nonetheless, we have noted that much of the upgrading can be realized through greater effort at conceptualization, more effective study planning, and a common, realistic expectation of what can be accomplished through a focussed, applied research programme.

The case studies have substantiated these views. Technical limitations, whatever their form or magnitude, are universal and will continue to apply. Practitioners must be aware of these when planning study programmes, as they

bear directly on what can be achieved in the laboratory or field. Despite these limitations, the foregoing analysis has identified some key opportunities where overcoming the non-technical barriers can lead to an upgrading of the ecological integrity of impact assessment.

In conclusion, the case studies have demonstrated that some improvements in the application of ecological and broader scientific concepts to environmental assessment are within the means of those who plan, undertake and review the assessments. As well, they have shown that constraints posed by the attitudes and perceptions of the persons and organizations involved may be equally, if not more, important than the technical and logistical limitations that may apply.

APPENDIX D

CONSIDERING THE ARCTIC ENVIRONMENT

"The Arctic archipelago, from a terrestrial point of view, mimics a united land mass during most of the year because the channels are frozen.

"The processes are the same; it's the rates that are different. Some are extremely slow; for example, succession and replacement. Others are very fast, especially reproductive activities."

"Arctic faunal processes are often quite different since the animals have adapted to different feeding regimes compared to their mid-latitude relatives."

"You could conceive of the Arctic as a giant river with numerous large islands. Water flow is generally from the Arctic Ocean through the channels in a southeasterly direction."

BACKGROUND

On the advice of the Project Advisory Committee, a separate workshop was held specifically to focus on the ecology of the Canadian Arctic with respect to the implications for environmental impact assessment. The rationale was that (i) major resource developments are being planned for the far north and it seemed inappropriate to ignore these in the project and (ii) although all ecosystems can be described using basic generic relationships, the unique characteristics of Arctic systems may pose substantial advantages and disadvantages for the conduct of impact assessments.

Basically, the workshop focussed on differences between the Arctic and more temperate latitudes with respect to the main ecological issues involved in impact assessment studies as determined by the previous nine workshops. The following text relies heavily on the direct contribution of the participants rather than on an extensive concomitant review of the Arctic literature. Thus, it was not possible to illustrate many of the issues and suggestions raised with specific examples from impact assessments or related studies. This is also a function of the few impact assessments conducted for Arctic developments, although this situation will soon change given the number of major projects at various stages in the planning process.

NON-TECHNICAL ISSUES

Combining Research and Assessment Needs

There seems to be general agreement that environmental impact assessment in the Arctic, in total or in part, must be attached to, or supported by, a researcn programme. Our knowledge of Arctic ecology is not as advanced as our ecological understanding in temperature latitudes. It has been suggested (Dunbar, 1976) that a lack of commercial interest in Arctic marine fishes has precluded research on population dynamics of many species, in contrast with decades of study on exploited species. It might be argued that the current high level of interest in developing the non-renewable resources of the North will stimulate such basic environmental research. However, based on experience to date, the major emphasis in frontier research has been on the effects of the environment on project facilities and operation rather than on the effects of development projects on Arctic biota (Lewis, 1979). Perhaps even more relevant is the time factor. Our understanding of more southern ecosystems, as limited as it is, has been accumulated over a long period of time. Since it seems unlikely that the frantic pace of northern development will slow down, the best opportunity may be to mount a concentrated research effort coupled with the present focus on exploitation and impact assessment activities.

Although our limited knowledge of Arctic ecology is a general constraint, there are exceptions. For example, as a result of the proposal to construct a large diameter natural gas pipeline along the MacKenzie River Valley in the early 1970's, a comprehensive field research programme was undertaken, the results of which make that area one of the better known regions of Canada (Anonymous, 1972). Similarly, the Beaufort Sea Project of the mid 1970's involved over 30 studies dealing with major aspects of the physical oceanography and marine biology of the Beaufort Sea (Milne, 1976). Although these research programmes may not have provided the insight which comes from continuous studies over long periods of time, they demonstrate the major advances in our understanding which can be achieved through co-ordinated and concentrated research efforts.

"I think there is a definite need for generic impact studies for Arctic systems."

"Let's not forget that for some Arctic areas we have a great deal of biological knowledge."

"Logistical and cost constraints are the most important ones for Arctic baseline studies."

"The logistics for impact assessment studies can be piggybacked onto engineering, exploration and operation logistics."

The Cost of Doing Business

By any standards, the cost of conducting research or undertaking impact assessment studies in the Arctic is very high. The financial investment related to transportation in

remote areas, logistical and support facilities, research hardware and study platforms can become exhorbitant. For example, in 1975, an oceanographic research vessel, properly equipped to operate in high latitudes, was estimated to cost about $10 million with 20 per cent of that amount required for annual operating funds (Hood, 1976a). The Beaufort Sea Project mentioned above cost over $11 million between 1973 and 1975 (Milne, 1976), and the BIOS project, a current research effort involving an experimental oil spill in the Arctic, is expected to cost over $7 million when direct and indirect costs are included (E. Birchard, pers. comm.). Not only are the financial burdens great but the information return on the investment may be much more limited than in temperate situations.

The obvious advantages of sharing the cost of such expensive undertakings between governments and industry have already resulted in a number of cooperative research programmes in support of environmental impact assessment. Examples in Canada include the Beaufort Sea Project, the Eastern Arctic Marine Environmental Studies (EAMES), the offshore Labrador Biological Studies (OLABS) and the BIOS project. Norton (1979) gave examples where such cooperative research efforts have also been undertaken in support of environmental impact assessments for hydrocarbon exploration and development offshore of Alaska.

In some cases, the co-operation may involve joint funding or the sharing of facilities and resources or both. With respect to the latter approach, a number of workshop participants urged that greater advantage be taken of piggybacking assessment studies and ecological research on early exploration and survey programmes.

Limited Expertise

Another handicap facing northern studies, whether oriented towards basic research or impact assessment, is a shortage of qualified scientists. The scientific community in Canada familiar with, and experienced in, Arctic studies is very limited, although it has grown significantly in recent years. This is also a general problem for impact assessments conducted in the more populated parts of the country, but it may become the limiting factor for northern studies since we cannot readily transfer our southern experience and intuition to the Arctic. In the words of Hood (1976b), "Experience has shown that most deductions based on experience outside the northern regions have been in error."

Assuming that the focus on developing Canada's north will not diminish, it is unlikely that there will be sufficient well trained and experienced scientists to meet the projected needs. This may pose a conundrum for those administering the assessment procedures. In the past, they have placed a high priority on undertaking an arms length technical review of the completed studies using experts who have not been involved. In the future, it may not be possible to retain Arctic experts in reserve as opposed to encouraging the maximum involvement of all qualified individuals, whether they work for governments or the private sector.

The shortage of qualified scientists may be only a part of the problem of limited expertise. As Norton (1979) noted in reference to the Alaskan/Beaufort experience, it took considerable effort to keep the best-qualified investigators involved in impact studies since environmental assessment in the conventional sense apparently was not very intellectually stimulating. The scientists were permitted to expand the scope of their work into the general need for information on off-shore development. In the words of Norton:

"Thus, we have biological investigators who, in 1975, originally set out to make basic surveys of the number and kinds of organisms present in the Beaufort, then continued by evaluating functional relationships of organisms to their habitats that accounted for clustering of unusual numbers in certain locations, then turned to evaluating the trophic interactions of key organisms' response to and recovery from very specific kinds of OCS (outer continental shelf)-related insults."

"Perhaps a serious constraint, for example, for terrain mapping in the Arctic, is the lack of capable experts."

"Since the high cost of doing Arctic studies is largely in getting and staying there, we should do excellent and intensive study while we can."

"Many natural events in the Arctic occur abruptly and unpredictably."

"Sea ice and snow cover in the Arctic are just not predictable."

"The high variability in the Arctic has both advantages and disadvantages. The major advantage is that you can focus on areas and times of concentrated biological activity. The disadvantage is that it's difficult to establish broad survey baselines."

Logistical Problems

The tremendous expanse of the Arctic raises important logistical questions concerning what to study and where. As well, as a result of many biotic processes being temporally compressed, the time available for field studies may be only a matter of weeks. Consequently, decisions regarding the deployment of study resources may be critical. For example, the annual spring phytoplankton bloom in any particular area may last only a week or two and careful planning is required if studies are to examine the bloom at the peak of primary production or biomass. Since many natural events in the Arctic are highly stochastic (e.g., the formation of polynyas in certain areas or the retreat of winter ice), studies often may need to run longer than initially anticipated in order to investigate major biotic perturbations.

In examining phenomena strongly influenced by climate and thus characterized by a high degree of spatial heterogeneity, advantage can be taken of more synoptic study techniques. For example, the latest advances in remote sensing techniques, in particular satellite imagery, have made possible the reliable identification of polynyas (Smith and Rigby, 1981).

A number of approaches have been suggested for dealing with the peculiar spatial and temporal nature of Arctic phenomena. Hood (1976b) proposed the selection of type areas which would be studied in detail until a satisfactory level of understanding is achieved, and the results then extrapolated to other areas. The workshop participants suggested that closer attention paid in study design to the overriding influence of microclimate on many terrestrial species and processes would be of great value. On the marine side, the participants spoke of the advantages of focussing the study efforts on ice-edge communities, polynyas, areas of upwelling and nearshore ecosystems.

The Need for Continuity

On account of the considerable cost and difficulty of acquiring data in remote and harsh areas, it is tempting to plan short-term studies for impact assessments of northern developments. However, it is precisely because of our poor understanding of the responses of Arctic systems to industrial activities that we need to continue study efforts until the most pressing questions are answered. In this context, Arctic projects are the prime candidates to be subjected to experimental study as discussed earlier in the report. Even the most optimistic proponents of northern developments would consider many proposed activities in the high Arctic as experimental in nature. The Arctic Pilot Project, a proposal to transport natural gas from the high Arctic by LNG tankers operating year round, is an example of such a large-scale experiment. It is generally agreed that there is insufficient knowledge or experience to predict the effects of noise from large ships on Arctic marine mammals. Nor is it known what the effects will be of the areas of open water left by the ships' passage in an otherwise ice-covered sea. In such cases, our knowledge must come from large-scale experiments since they appear to be the only avenue for answering many critical ecological questions.

UNIQUE CHARACTERISTICS OF ARCTIC ECOSYSTEMS

"The Arctic marine environment does present taxonomic problems, but on the basis of ecological function it may be simpler than the number of species (as indicated by morphology) may lead you to believe."

"It seems to me that Arctic ecosystems have well-sorted components, and thus they are easier to separate and bound on paper."

"The replacement of destroyed habitat in terrestrial Arctic ecosystems is not an available option."

"In the Arctic you often get the case where the populations that concentrate into colonies, herds or schools represent large proportions of the world's total supply of those species."

"The low productivity of Arctic waters results mainly from the poor circulation of nutrients and carbon — they get locked low below the euphotic zone."

Arctic ecosystems operate according to the same basic functional principles as do tropical and temperate ecosystems. However, they exhibit variations on these principles which may have implications for undertaking environmental assessment.

Marine primary productivity is a prime example of such variations. The spring bloom of marine algae, constituting a period of maximum biomass accumulation, is brief but extremely significant for Arctic marine systems since it provides the bulk of the energy which powers the entire marine trophic structure. The bloom is controlled primarily by three factors — nutrient availability, light, and stability of the water column. While one might initially expect a wave of phytoplanktonic production to move northward with increased day length and more direct sunlight as summer approaches, the factor of water column stability, controlled to a significant degree by ice, plays a significant role in altering this pattern. Thus, the bloom generally appears earlier in stable surface waters than it does in turbulent, open waters, even though such stable waters may be much further north.

The resulting patchiness of the spring phytoplankton bloom may indeed lengthen the season of heightened biomass production on a regional basis. This can be important for opportunistic feeders higher in the trophic structure whose ranges are broad enough to allow them to continually utilize local phytoplankton blooms and the attendant burst of secondary production.

It was pointed out by a number of the workshop participants that the spring bloom may be difficult to study for two reasons. First, since it occurs over a relatively brief period and is not entirely predictable, there is either a risk of missing the bloom at specific study locations or a need to spend an inordinate amount of time at a study location waiting for the bloom to occur. Secondly, the bloom often occurs during the period of spring break up of ice, the most difficult time during the Arctic marine field season from a logistics point of view. The ice is often too weathered to be a safe study platform but may be sufficiently dense in some areas to inhibit navigation. According to some participants at the workshop, a concentrated study effort on the spring bloom might necessitate a major commitment of financial resources for helicopter rental, the only reliable means of conducting tests over a wide area in a short period of time under adverse ice conditions. Having said this, there was no total agreement on the need to study the spring bloom in detail in spite of its obvious ecological importance.

The Arctic is also characterized by relatively short food chains and abbreviated pre-adult life stages. While these are not unique to Arctic ecosystems, they do offer some advantages for study. For example, based on studies in Prudhoe Bay (Feder and Schamel, 1976) it was shown that benthic organisms were the main food source for a number of important fish species. Furthermore, many benthic species in the Arctic have greatly abbreviated pelagic life cycle stages, resulting in the development of relatively localized populations that depend mainly on self-recruitment. Thus, these species are excellent indicators for use in a monitor-

ing programme since (i) they generally are susceptible to oil contamination and (ii) the impacts would be less likely to be masked by external recruitment into the area. Examination of these same benthic organisms would reveal the long recovery time for many Arctic species that are slow to reach sexual maturity.

Unusual concentrations of biota in space and time are also characteristic of the Arctic environment. Many species of marine mammals and seabirds come together in major concentrations during the brief summer to breed and to rear their young. For example, about 5 000 beluga whales are known to inhabit parts of the MacKenzie River Delta during the summer months (Lewis, 1979). Estimates of breeding seabirds on Prince Leopold Island range up to 600 000 individuals of various species (Nettleship, 1975). Similarly, Truett (1980) reported that an estimated several million Arctic cod swept through the particular lagoon under study in one season, although they were at normal lower levels of abundance the years before and after that season.

Such dense concentrations are likely related to the high levels of primary production during the spring bloom and the subsequent growth of higher trophic level populations. In any event, the main concern for impact assessment in the Arctic is often related to vulnerability — where and when will species be concentrated and what is the probability that they will be impacted by the project? In this context, transport mechanisms in the Arctic marine environment (for example, as represented by oil slick trajectory models) become extremely important when compared with the known distributions of organisms.

From an operational point of view, the question of vulnerability can be mitigated by avoidance. However, in the event that marine drilling projects are suspected of posing a severe threat to certain concentrations of organisms, a consideration of avoidance may result in serious limitations on project operations. For example, based on the results from a few years of seabird monitoring as part of the assessment for the South Davis Strait project (Imperial Oil Ltd. *et al.*, 1978), it was suggested that the exploratory drilling program should be halted during the period of migration. If the advice has been taken, the 10-week drilling season would have been shortened by 4 weeks! (S. Conover, pers. comm.).

"One advantage of the Arctic is the limited spatial extent of areas where fauna undertake their major life-cycle events."

"The opportunities for recruitment in disturbed Arctic populations are much fewer than in populations in temperate areas."

"While the life histories of Arctic species may be long, most of them have very short, life-cycle events."

"The Arctic offers numerous opportunities for easily avoiding times and areas of biotic productivity."

"The timing and areas of concentrated primary production do not necessarily mean that the species of importance, which are usually homeotherms, are present at that time."

"Industrial activity should take advantage of the absence of biological activity during the Arctic winter. The problem then becomes the darkness!"

CALIBRATION OF BIOLOGICAL WITH PHYSICAL PHENOMENA

Hood (1976a), in discussing the importance of Arctic Ocean studies, stressed the fact that northern biological communities are, "either partially or wholly dependent on the sequence of well-timed events in the Arctic." Throughout their evolutionary history, northern species have adapted to take advantage of the brief but highly productive Arctic summer. However, this calibration of biological and physical phenomena is not perfect and any 'slippage' of physical events, even for a few days, can be disastrous for some species.

A number of authors have made reference to the serious effects on certain species resulting from years of unusual ice accumulation. For example, according to Milne (1976), "the heavy ice in the spring of 1974 appeared to have nearly catastrophic effects on the higher life forms in the Beaufort Sea, such as the snow geese which failed to reproduce successfully, the slower growth rates evident in ringed seals, and the incidence of starving bears." Stirling and others (1981) reported that the population of ringed seals in the same year dropped by about 50 per cent and reproduction was reduced by about 90 per cent.

Similarly, Brown and Nettleship (1981) reported that when the polynya at the eastern end of Lancaster Sound failed to develop in 1978, only 10-20 per cent of some colonial seabird species attempted to breed, presumably owing to a sharp reduction in food supply. While it is obvious that the species have been able to accommodate such disastrous reductions in their populations, the question remains about the long-term effects of major man-induced perturbations, especially if they occur coincidental with, or immediately subsequent to, such natural catastrophes.

It appears that predicting changes in physical phenomena in the Arctic, especially phenomena influenced strongly by climate, is no less difficult than for biological variables. This certainly seems to be the case with ice formation, distribution and breakup, which are highly variable from year to year.

ICE-RELATED PHENOMENA

According to Dunbar (1981), "Both the presence and absence of ice in the north have special biological significance." The focus in the following discussion will be on three ice-related phenomena — epontic (under ice) primary production, ice-edge ecosystems and polynyas.

Primary Production under Sea Ice

The presence of ice has, among others, the following three effects on marine primary production: (i) it reduces light penetration, thus limiting phytoplankton production in the water column, (ii) it stabilizes the water column, especially at the surface, thus promoting production, and (iii) it allows epontic algae to attach to its undersurface, thus promoting production. The bloom of the epontic algae community (sometimes referred to as 'an inverted benthic community,' which includes associated fauna) is much more characteristic of the expected south to north wave as spring progresses and it usually precedes the phytoplankton bloom in nearby open water. Thus, the total length and production of the spring bloom of marine primary production at a particular site where ice occurs can be increased significantly. It has been estimated that epontic primary production may account for as much as one-quarter of marine primary production in some Arctic locations.

Ice-Edge Ecosystems

The edge of sea ice is known to be biotically active. Primary production is relatively high at the water-ice interface where it supports a variety of higher trophic level organisms including Arctic cod, seabirds and marine mammals (Dunbar, 1981). In the early spring, open-water leads are particularly important as they provide, in otherwise complete ice cover, extensive ice-edges which appear to be of great significance to migrating sea birds.

This phenomenon is also important when considering the potential effect of an oil spill. For example, it has been shown that oil, when released under ice, will eventually find its way to the surface of the ice and will accumulate in areas of open water including ice leads (Lewis, 1979). It is also obvious that an oil spill on open water may accumulate along an ice edge.

As a priority for study in environmental impact assessments of Arctic marine developments, the ice-edge ecosystem ranks with the nearshore communities since they both represent areas which may bear the brunt of any major oil spill.

Polynyas

Polynyas are areas of open water surrounded by ice. They may remain open all or part of the year and they may recur in approximately the same location year after year (recurring polynyas). Individual polynyas have been known and studied for some time but the recent work by Stirling and Cleator (1981) is the first comprehensive review of polynyas throughout the Canadian Arctic. Although the exact mechanisms responsible for creating individual polynyas may vary, they are generally considered to be the result of the forces of wind, currents, upwelling, and vertical mixing.

Polynyas are important as refuges for a wide variety of seabirds and marine mammals which take advantage of the improved access to air, water, and ice, and possible higher levels of production. For example, Brown and Nettleship (1981) showed that there is a distinct relationship between the distribution of major colonies of most Arctic seabirds and the occurrence of polynyas, presumably related to the advantages that the open water provides in securing food during the early stages of breeding.

The potential importance of polynyas when one considers the effects of northern ship transportation or major oil releases is obvious. In the words of Stirling and others (1981), "An oil spill or blowout in a polynya area could be particularly devastating to species with restricted winter distribution if the availability of undisturbed polynyas for feeding and breathing was critical to their continued survival."

CLOSING REMARKS

In the discussions on developing a study strategy (Chapter 9), it was suggested that impact assessment studies could be substantially upgraded without launching into the 'cutting edge of science.' This is probably true for assessments conducted in more temperate regions of the country where there is little evidence to show that advantage is being taken of basic knowledge of well-documented phenomena. However, as evidenced by the above outline, in the Arctic we are often dealing with unique ecosystems of which there is a more limited understanding. This ignorance in itself should raise the importance which is attached to potential impacts on such systems. Thus, in the Arctic, basic research and assessment studies should begin to merge operationally, although the motivations for each remain quite different.

The smart research managers are capitalizing on the high level of interest in Arctic development by modifying their programmes to support some aspects of impact assessment studies and thereby securing funds and the use of 'research platforms' that might otherwise not be available. Those who are confining their interests to more conventional bases of research support may be missing an important opportunity.

For environmental impact assessment in the Arctic, the words of Dr. M.J. Dunbar, as quoted by Livingston (1981), are particularly appropriate:

> ". . . the most important requisite is basic research, something that should have been obvious from the start. There is a school of thought that believes that ideal impact studies, successful in predicting accurately the result of accidents and industrial wastes, may well be impossible. Nevertheless, it has at least become clear, even to the most refractory minds, that, in order to come even close to the ability to predict such effects, it is necessary to know precisely and simply how nature works in the particular context at issue. What is needed is basic science, not 'integrated, interdisciplinary, mission-oriented' jargon."

"Since many Arctic impacts are catastrophic or accidental, the use of experiments to study these beforehand is limited."

"The benthic Arctic marine environment is very stable and very predictable."

"Because extremes in biological parameters are so obvious and spectacular in the Arctic, I would think they should be easier to document."

"Sociopolitical sensitivities of northern issues are often a major constraint to Arctic impact assessment studies. We can't put radio collars on caribou because the natives don't want it."

"In general, we can say that areas of annual ice cover are more productive than areas of multi-year ice."

"Once you know the relationships and associations between the animals and the ice, prediction on the basis of ice types can be a very useful approach."

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